FORM PTO-1390 (REV. 1-98) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

PCT 4

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
1907-190PCT
U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/508613 NEW

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP98/03963	03 September 1998	19 September 1997

412 Rec'd PCT/PTO 17 MAR 2000

TITLE OF INVENTION
IMAGE ENCODER AND IMAGE DECODER

APPLICANT(S) FOR DO/EO/US
ITO, Norio; HASEGAWA, Shinya; KUSAO, Hiroshi; KATATA, Hiroyuki; AONO, Tomoko

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)) (W099/16249 in Japanese)
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(3)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(2)).
   a. ☒ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☒ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98./International Search Report with cited references
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:

    1.) Translation of Replacement Sheets (9 Sets)
    2.) Thrity-Eight (38) Sheets of Formal Drawings
    3.) One (1) Sheet of Drawing Filed Under Article 34

514 Rec'd PCT/PTO 17 MAR 2000

U.S. APPLICATION NO (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/508813	PCT/JP98/03963	1907-190PCT

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO. **$970.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$840.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. **$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$670.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4). **$96.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 840.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ ---------	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	130 - 20 =	110	X $18.00	$ 1980.00	
Independent Claims	7 - 3 =	4	X $78.00	$ 312.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		Yes	+ $260.00	$ 260.00	
TOTAL OF ABOVE CALCULATIONS =				$ 3392.00	
Reduction of ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				$ ---------	
SUBTOTAL =				$ 3392.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐20 ☐30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$ ---------	
TOTAL NATIONAL FEE =				$ 3392.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$ 3432.00	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of $ 3432.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account. No. ___________ in the amount of $_______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-2448.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to:

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SIGNATURE Terrell C. Birch

BIRCH, TERRELL C.
NAME

#19,382 (TCB)
REGISTRATION NUMBER

/TCB/sas March 17, 2000

09/508813

514 Rec'd PCT/PTO 17 MAR 2000

PATENT
1907-190P

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant:	N. ITO et al.		
Int'l. Appl. No.:	PCT/JP98/03963		
Appl. No.:	NEW	Group:	
Filed:	March 17, 2000	Examiner:	
For:	IMAGE ENCODER AND IMAGE DECODER		

PRELIMINARY AMENDMENT

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, DC 20231

March 17, 2000

Sir:

The following Preliminary Amendments and Remarks are respectfully submitted in connection with the above-identified application.

AMENDMENTS

IN THE SPECIFICATION:

Please amend the specification as follows:

Before line 1, insert --This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/JP98/03963 which has an International filing date of September 3, 1998, which designated the United States of America.--

IN THE CLAIMS *(as amended & received by I.B. on Feb. 22, 1999)*:

Please amend the claims as follows:

Claim 7 (amended)

Line 2, change "6," to --5,--;

Claim 8 (amended)

Line 2, change "7" to --5--;

Claim 9 (amended)

Line 2, change "8," to --5,--;

Claim 10 (amended)

Line 2, change "8," to --5,--;

Claim 16 (amended)

Line 2, change "15," to --14,--;

Claim 17 (amended)

Line 2, change "16" to --14--;

Claim 18 (amended)

Line 2, change "17," to --14,--;

Claim 19 (amended)

Line 2, change "17," to --14,--;

Please add the following new claims:

-- 20. An image coding device as defined in claim 6, wherein the wavelet coding portion performs multiple times the subband decomposition process by selectively applying suitable filters for respective subbands.

21. An image coding device having a combination of plural coding modes selectable from claim 6 and having a plurality of selectively applicable coding modes, which further includes a flag generator for generating flags indicating respective coding modes and a control portion for controlling the coding device in a mode specified by the flag generated by the flag generating portion, wherein the management information generating portion generates management information including the flags generated by the flag generating portion.

22. An image coding device having a combination of plural coding modes selectable from claim 7 and having a plurality of selectively applicable coding modes, which further includes a flag generator for generating flags indicating respective coding modes and a control portion for controlling the coding device in a mode specified by the flag generated by the flag generating portion, wherein the management information generating portion generates management information including the flags generated by the flag generating portion.

23. An image coding device as defined in claim 6, wherein an ID generating portion for generating IDs for identifying respective tiles is further provided and the management information generating portion generates management information including the IDs generated by the ID generating portion.

24. An image coding device as defined in claim 7, wherein an ID generating portion for generating IDs for identifying respective tiles is further provided and the management

information generating portion generates management information including the IDs generated by the ID generating portion.

25. An image coding device as defined in claim 8, wherein an ID generating portion for generating IDs for identifying respective tiles is further provided and the management information generating portion generates management information including the IDs generated by the ID generating portion.

26. An image coding device as defined in claim 6, which further includes an ID generating portion for generating IDs for identifying respective tiles and an adjacent tile ID deciding portion for generating IDs of adjacent tiles around an objective tile to be coded by using ID information from the ID generating portion and tile information from the wavelet coding portion, wherein the management information generating portion generates management information including the IDs and the IDs of adjacent tile.

27. An image coding device as defined in claim 7, which further includes an ID generating portion for generating IDs for identifying respective tiles and an adjacent tile ID deciding portion for generating IDs of adjacent tiles around an objective tile to be coded by using ID information from the ID generating portion and tile information from the wavelet coding portion, wherein the management information generating portion generates management information including the IDs and the IDs of adjacent tile.

28. An image coding device as defined in claim 8, which further includes an ID generating portion for generating IDs for identifying respective tiles and an adjacent tile ID deciding portion for generating IDs of adjacent tiles around an objective tile to be coded by using ID information from the ID generating portion and tile information from the wavelet coding portion, wherein the management information generating portion generates management information including the IDs and the IDs of adjacent tile.

29. An image decoding device as defined in claim 15, wherein the wavelet decoding portion repeats multiple times the subband composition with use of filters changeable every iteration.

30. An image decoding device having a combination of plural decoding systems selectable from claim 15 and having plural decoding modes selectively applicable, which further includes:

a management information separating portion for separating management information necessary for decoding each tile and each subband from the input coded data;

a flag extracting portion for extracting from the management information a flag for specifying a decoding mode used for decoding the coded data from the management information; and

a control portion for controlling the decoding device to be activated in a decoding mode corresponding to the extracted flag.

31. An image decoding device having a combination of plural decoding systems selectable from claim 16 and having plural decoding modes selectively applicable, which further includes:

a management information separating portion for separating management information necessary for decoding each tile and each subband from the input coded data;

a flag extracting portion for extracting from the management information a flag for specifying a decoding mode used for decoding the coded data from the management information; and

a control portion for controlling the decoding device to be activated in a decoding mode corresponding to the extracted flag.

32. An image decoding device as defined in claim 15, which further includes a control portion for controlling inputting of coded data to the wavelet decoding portion according to ID information so as to decode only a tile having a specified ID by the wavelet decoding portion.

33. An image decoding device as defined in claim 16, which further includes a control portion for controlling inputting of coded data to the wavelet decoding portion according to ID information so as to decode only a tile having a specified ID by the wavelet decoding portion.

34. An image decoding device as defined in claim 17, which further includes a control portion for controlling inputting of coded data to the wavelet decoding portion according to ID information so as to decode only a tile having a specified ID by the wavelet decoding portion.

35. An image decoding device as defined in claim 15, which further includes a buffer memory for storing input coded data and a control portion for controlling the data from the buffer according to ID information and adjacent tile ID information in management information from the management information separating portion so that coded data only for an objective tile having a specified ID and related adjacent tiles having respective IDs is outputted from the buffer memory and inputted to the wavelet coding portion to decode only the specified tile and the adjacent tiles.

36. An image decoding device as defined in claim 16, which further includes a buffer memory for storing input coded data and a control portion for controlling the data from the buffer according to ID information and adjacent tile ID information in management information from the management information separating portion so that coded data only for an objective tile having a specified ID and related adjacent tiles having respective IDs is outputted from the buffer memory and inputted to the wavelet coding portion to decode only the specified tile and the adjacent tiles.

37. An image decoding device as defined in claim 17, which further includes a buffer memory for storing input coded data and a control portion for controlling the data from the buffer according to ID information and adjacent tile ID information in management information from the management information separating portion so that coded data only for an objective tile having a specified ID

specified ID and related adjacent tiles having respective IDs is outputted from the buffer memory and inputted to the wavelet coding portion to decode only the specified tile and the adjacent tiles. --

REMARKS

Claims 1-37 are pending in this application. New claims 20-37 have been added in this Preliminary Amendment.

The specification has been amended to provide a cross-reference to the previously filed International Application.

The claims have been amended to corrected improper multiple dependency format and to place them in better form for U.S. practice.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

By ______________________
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TCB/pjh
1907-190P

09/508813
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38/PRTS

SPECIFICATION

IMAGE ENCODER AND IMAGE DECODER

FIELD OF THE INVENTION

The present invention generally relates to the field of digital image processing and, more specifically, to an image coding device for encoding digital image data with high efficiency and an image decoding device for decoding coded data encoded by the image coding device.

BACKGROUND OF THE INVENTION

Flash Pix format specification version 1.0 has been proposed as an image format for converting natural image data into digital data suitable for computer processing.

This format specification permits a plurality of data with different resolutions to be stored together therein so that any data suited to an actual display and/or printing device can be selected and taken-out promptly in response to a user's request. Furthermore, each image is divided into tiles arranged in the format that allows the user to select only a necessary data portion of the image and process it in an enlarged or reduced size with a reduced processing load.

Referring to Figures 1 and 2, an image coding device for encoding an image according to the flash pix format is described as follows. In Fig. 1, images are shown in different reduced

scales, each of which are divided into tiles. Figure 2 is a block diagram of an exemplary image coding device.

The flash pix method is featured in that it generates first images 1 to 4 in sizes 1/1 to 1/8, as shown in Fig. 1, then divides each image into tiles and compresses data of each tile image.

First, a case of encoding an image 1 shown in Fig. 1 by the coding device of Fig. 2 is described. In Fig. 1, a dashed line shows the boundary between tiles.

A tile decomposition portion 11 divides an original image into tiles each comprising 64 x 64 pixels, which tiles are then compressed one by one by a JPEG compressor portion 12. In a coded-data integration portion 13, coded data of each tile is combined with tile decomposition information from the tile decomposition portion 11 to form coded data 1 to be output.

The image 2 of Fig. 1 is described. The original image 0 is reduced to 1/2 in length and width by a 1/2 contraction portion 14, and then the 1/2-size image is processed through a tile decomposition portion 15, a JPEG compressing portion 16 and a coded-data integration portion 17 to form coded data 2.

Size reduction of the image to generate a group of size-reduced images in Fig 1 (Images 2 to 4) is repeatedly performed until a downsized image containable within a single tile is obtained. For example, the image 3 is still larger than a tile and is further contracted by a factor of 2 to obtain

the image 4 allowable within a single tile as shown in Fig. 1. The size-reduction procedure is now finished.

Coded data for the image 3 is produced through a 1/2 contraction portion 18, a tile decomposition 19, a JPEG compressing portion 20 and a coded data integration portion 21. Coded data for the image 4 is produced through a 1/2 contraction portion 22, a tile decomposition portion 23, a JPEG compressing portion 24 and a coded data integration portion 25.

However, the above-described system involves the following problems: Storing coded data for images downsized with different resolutions in addition to coded data for the image with the scale 1:1 results in increasing a volume of coded data by a factor of 1.4. Furthermore, compression for encoding data must be done for each resolution image, resulting in considerably increasing processing load.

On the other hand, apart from the Flash Pix method, the image compression can be also accomplished by the wavelet transform technique whereby image data with different resolutions can be easily decoded from coded and compressed data of an original-size image. This technique is therefore free from the problem with increasing the amount of coded data.

Namely, the wavelet transform method can meet the demand for decoding data with different resolutions without any increase of coded data whereas the Flash Pix method has an increase by a factor of 1.4 in volume of coded data.

Figure 3 is a basic block diagram of a wavelet transform coding portion wherein an original image is converted by a wavelet transform portion 31 into data for subband divisions, which data is quantized by a quantizing portion 104 and then entropy encoded by an entropy coding portion 33 to produce coded data. The wavelet transform portion 31, quantizing portion 32 and entropy coding portion 33 composes a so-called wavelet coding portion 34.

Figure 4 is a detailed block diagram of the wavelet transform portion 31 of Fig. 3.

Figure 5 depicts an example of the wavelet transformation of an image. Figures 4 and 5 are shown as an example of conducting two-dimensional subband decomposition three times.

An original image shown in Fig. 5A is filtered through a horizontal low-pass filter 41 and a horizontal high-pass filter 42 to create two horizontal subbands that are then decimated to 1/2 respectively by 1/2-subsampling portions 47 and 48.

Two horizontally divided subbands are divided each into two subbands through vertical low-pass filters 43, 45 and vertical high-pass filter 44, 46, which subbands are decimated each to 1/2 by 1/2 sampling portions 49 to 52. Consequently, four subbands are formed.

A high-horizontal and high-vertical frequency subband j (Fig.4), a high-horizontal and low-vertical frequency subband i (Fig. 4) and a low-horizontal and high-vertical frequency subband h (Fig. 4) correspond to wavelet transform coefficients

h, i and j (Fig. 5B) respectively.

After this, only a remaining low-horizontal and low-vertical frequency subband 53 is recursively divided into subbands.

This recursive subband decomposing process is performed by horizontal low-pass filters 54, 66, horizontal high-pass filters 55, 67, vertical low-pass filters 56, 58, 68, 70, vertical high-pass filters 57, 59, 69, 71 and 1/2-sampling portions 60-65, 72-77.

Sub-bands a-g (Fig. 4) correspond to sub-bands a-g (Fig. 5B) respectively.

Wavelet transform coefficients shown in Fig. 5B are quantized on a subband-by-subband basis by a quantizing portion 32 (Fig. 3) and then entropy encoded by an entropy coding portion 33 to produce coded data. The entropy-coding portion 33 may use Huffman coding or arithmetic coding.

On the other hand, wavelet-coded data is decoded by an entropy decoding portion 81 and inversely quantized by an inverse quantizing portion 82. Subbands are then combined by an inverse wavelet transform portion 83 to produce a decoded image. The entropy decoding portion 81, inverse quantizing portion 82 and inverse wavelet transform portion 83 compose a so-called wavelet decoding portion 84.

Image-encoding using the wavelet transform technique is featured by hierarchical structure according to resolution levels as shown in Fig. 5B. This method can easily decode images

having different resolution levels from a part of coded data or a whole coded data.

Namely, an image of a quarter (1/4) the original image size can be decoded by decoding subbands a, b and c. An image of a half (1/2) the original image size can be decoded by decoded subbands a, b, c, e, f and g. A complete (1/1) size image can be produced by decoding all subbands.

Referring to Fig. 7, the operation of the horizontal low-pass (H-LP), horizontal high-pass (H-HP), vertical low-pass (V-LP) and vertical high-pass (V-HP) filters shown in Fig. 4 will be described as follows. Figure 7B is an enlarged view of an encircled part B' of Fig. 7A.

When an output of a horizontal 9 tap filter, associated with a pixel 91 positioned right top on the original image is calculated for wavelet transformation of an original image, the operation of the filter must be performed on an area 92.

However, a part of the objective area 92 is out of the boundary of the original image, where no data exists. The vertical filters may also encounter with a similar problem.

Thus, for operation on the periphery of the image, it is often needed to use external data outside the image boundary according to the number of the taps of the filter used. Iteration of the subband decomposition also results in enlarging the area into which the filter extrudes.

In general, the above problems are treated in such a manner that the image is folded at its periphery according to a certain

given rule.

For the Flash Pix method using a plurality of coded data sets separately provided for respective images of different resolution levels, the image processing load such as enlargement or contraction of the image can be reduced, but the data size is increased to 1.4 times.

For wavelet-transform coding method, data with different resolution levels can be easily decoded from a single set of compressed and coded data for an original image size and, therefore, no increase in the data size takes place.

When the wavelet-transform coding system utilizes the method of decomposing an image into tiles and encoding the image data on a tile-by-tile basis, which is used in the flash-pix system (to reduce the processing load by selectively processing only necessary tiles in case of processing a particular part of the image), however, this arises the above-described problem since filters may stick from the boundary of respective tiles.

In other words, the flash pix system using the JPEG coding can easily perform coding of each tile owing to the closed property of coding in each tile, while the wavelet-transform coding system can not effectively use the above tile-by-tile coding-and-managing method because the processing causes the extrusion of filters out of respective tiles.

In addition, the conventional wavelet-transform coding system must have a memory sufficient for storing an output of the wavelet-transform portion 31 (Fig. 3), i.e., all wavelet

transform coefficients as shown in Fig. 5B. Since these coefficients have the same resolution as that of the original image, the memory has to possess a large capacity. This requirement becomes severer when processing a higher resolution image.

SUMMARY OF THE INVENTION

In view of the above-described problems of the prior arts, the present invention was made to provide a compact hardware system that realizes effective encoding of images with different resolutions and effective management of coded data by tiles by using an improved wavelet-transform technique.

Accordingly, an object of the present invention is to provide an image coding and decoding system by which the image is effectively encoded and easily decoded with any resolution level desired by the user with no increase in volume of coded data.

This is a great advantage of the present invention system as compared with the conventional Flash Pix system using the JPEG coding method, which has an increased amount to 1.4 times of code data to provide a plurality of images having different resolutions.

Another object of the present invention is to provide an image-coding and decoding system in which an image is decomposed into tiles and encoded on a tile-by-tile basis and the coded tiles can selectively decoded on the same principle

by using the wavelet-transform coding/decoding technique. This could not be accomplished by the conventional wavelet-transform coding/decoding system because it is difficult in principle to apply the wavelet transform to closed tiles of the image.

Another object of the present invention is to provide an image coding and decoding system that encodes an image on a tile-by-tile basis and allows the coded image to be partially decoded by selectively decoding only necessary tiles (without the necessity of decoding a whole image), thus improving the random access function of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a view for explaining how to reduce an image in size and decompose each image into tiles by a prior art.

Figure 2 shows an exemplary coding device for encoding an image 1 shown in Fig. 1.

Figure 3 is a basic block diagram of a wavelet-coding portion.

Figure 4 is a detailed block diagram of a wavelet transform portion.

Figure 5 is a view for explaining a correlation between an original image and wavelet-transformed data.

Figure 6 is a basic block diagram of a wavelet decoding portion.

Figure 7 is a view for explaining vertical and horizontal

filters for wavelet-transform of an original image.

Figure 8 is a block diagram of an image coding device according to an embodiment 1 of the present invention.

Figure 9 is view for explaining the operation of an image coding device according to the embodiment 1 of the present invention.

Figure 10 shows an exemplified bit stream in an image coding device according to the embodiment 1 of the present invention.

Figure 11 shows another exemplified bit stream in an image coding device according to the embodiment 1 of the present invention.

Figure 12 is view for explaining the operation of an image coding device that is an embodiment 2 of the present invention.

Figure 13 is a block diagram of an image decoding device according to an embodiment 3 of the present invention.

Figure 14 is view for explaining the operation of an image decoding device according to an embodiment 4 of the present invention.

Figure 15 is a block diagram of an image coding device according to an embodiment 5 of the present invention.

Figure 16 is view for explaining the operation of an image coding device according to the embodiment 5 of the present invention.

Figure 17 is view for explaining the operation of an image coding device according to an embodiment 6 of the present invention.

Figure 18 is a block diagram of an image coding device according to an embodiment 7 of the present invention.

Figure 19 is view for explaining the operation of an image coding device according to the embodiment 7 of the present invention.

Figure 20 is a block diagram of an image decoding device according to an embodiment 8 of the present invention.

Figure 21 is a block diagram of an image decoding device according to an embodiment 9 of the present invention.

Figure 22 is a block diagram of an image coding device according to an embodiment 10 of the present invention, with a view for explaining the operation of the same device.

Figure 23 is a block diagram of an image decoding device according to an embodiment 11 of the present invention, with a view for explaining the operation of the same device.

Figure 24 is a block diagram of an exemplary image coding device according to an embodiment 12 of the present invention.

Figure 25 is a block diagram of another exemplary image coding device according to the embodiment 12 of the present invention.

Figure 26 is a block diagram of another exemplary image coding device according to the embodiment 12 of the present invention.

Figure 27 is a block diagram of an exemplary image decoding device according to an embodiment 13 of the present invention.

Figure 28 is a block diagram of another exemplary image

decoding device according to the embodiment 13 of the present invention.

Figure 29 is a block diagram of another exemplary image decoding device according to the embodiment 13 of the present invention.

Figure 30 is a block diagram of an exemplary image coding device according to the embodiment 14 of the present invention.

Figure 31 shows an exemplified bit stream in an image coding device according to the embodiment 14 of the present invention.

Figure 32 is a block diagram of another exemplary image coding device according to the embodiment 14 of the present invention.

Figure 33 is a block diagram of another exemplary image coding device according to the embodiment 14 of the present invention.

Figure 34 is a block diagram of another exemplary image coding device according to the embodiment 14 of the present invention.

Figure 35 is a block diagram of an image decoding device according to an embodiment 15 of the present invention.

Figure 36 is a block diagram of an exemplary image coding device according to an embodiment 16 of the present invention, with a view for explaining the operation of the same device.

Figure 37 is a block diagram of another exemplary image coding device according to the embodiment 16 of the present invention.

Figure 38 shows an image decoding device according to an embodiment 17 of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 8 is a block diagram showing the construction of an image coding device that is an embodiment 1 of the present invention.

Image data of an original image as shown in Fig. 9A is decomposed by a tile decomposition portion 101 into tiles each of predetermined N pixels by M pixels. The decomposed image is shown in Fig. 9B. The tile decomposition portion 101 outputs N pixels by M pixels image in a tile as corresponding data to each tile.

Further processing will be described by way of example on a tile "i" in Fig. 9B. Image data of the tile "i" is divided by a wavelet transform portion 102 into subbands.

Data at the periphery of a tile is extrapolated when dividing the tile portion near its boundary into subbands. For example, as shown in Fig. 7B, an area 92 covered by a wavelet transform filter exists out of a tile. In this case, it is needed to add data at the periphery of the tile. The wavelet transform portion 102 therefore extrapolates data at the periphery of each tile and divides the tile into subbands.

The data extrapolation is achieved for example by generating a mirror image by outwardly folding an internal image of the tile as shown in Fig. 9C. A quantizing portion

103 quantizes wavelet transform coefficients and an entropy coding portion 104 performs entropy coding of the coefficients to obtain coded data of the tile "i".

The entropy coding can be achieved by using a known Huffman coding method or arithmetic coding method. The wavelet transform portion 102, quantizing portion 103 and entropy coding portion 104 composes a so-called wavelet transform coding portion 105.

On the other hand, a management information generating portion 106 generates information for identifying and managing tiles and subbands by using information on spatial locations of each tile from the tile decomposition portion 101 and information on each subband from the wavelet transform coding portion 105. The management information is utilized by a coded data integration portion 107.

Using the management information from a management information generating portion 106, the coded data integration portion 107 arranges and integrates information on the coded data from the entropy coding portion and adds the management information to a bit stream to generate coded data.

Management of the coded data according the tiles and subbands is needed for achieving decoding of a coded image at different resolution levels as shown in Fig. 1 or a particular tile or tiles of the coded image.

Figure 10 shows an example of a bit stream of coded data produced in the above-described manner. The bit stream is

composed of a header for managing information on a whole bit stream and information on each tile. Information for each tile consists of a tile header for managing the tile information and coded information representing a tile image encoded by the wavelet transform coding portion 105.

The tile header includes information on bit positions corresponding to respective subbands. A bit sequence corresponding to necessary one of the subbands can be found by accessing this information.

The structure of bit streams used in the system of the present invention is not limited to that shown in Fig. 10. For example, a sequence (I) A of Fig. 11 is similar to the sequence of Fig. 10, while a sequence (II) of Fig. 11 has the form in which each subband for a tile is separated and rearranged with a tile header added thereto. The latter sequence (II) allows the system to quickly reproduce a desirable contracted image by accessing only necessary tile or tiles in the sequence.

An image coding device according another embodiment 2 of the present invention will be described as follows. The image coding device of the embodiment 2 is similar in construction to the embodiment 1 shown in Fig. 8 but differs from the embodiment 1 described above with the figure 8 by the operation of the tile decomposition portion 101, which will be described below with reference to Fig. 12.

While the tile decomposition portion 101 of the embodiment 1 decomposes an image into tiles each of N pixels by M pixels

and outputs only image data within each tile to the wavelet transform portion 102, the tile decomposition portion 101 of embodiment 2 outputs image data obtained by multiplying the original image by a suitable window function.

For example, in case of extracting a tile "ij", the output of the tile decomposition portion 101 is a result of multiplying the original image data by a window function FX_i in the horizontal direction and by a window function Fy_j in the vertical direction. i denotes a horizontal tile number and j denotes a vertical tile number.

This means that the output of the tile decomposition portion 101 represents a weighted result of multiplying a shaded image portion (Fig. 12) by a weight corresponding to window functions. Window functions are such that a total of functions over a whole area is equal to 1. Window functions satisfying the following conditions are used.

$\Sigma FX_i(x)=1 \quad (0 \leqq x \leqq w)$

$\Sigma FY_j(y)=1 \quad (0 \leqq y \leqq h)$

where, w is the width of the original image, h is the height of the original image, x and y are the axes of abscissa and ordinate, respectively, with the origin at the top right corner of the original image.

A total of the functions $FX_i(x)$ is taken for i and $FY_j(y)$is taken for j. In Fig.12, FX_{i-1}, FX_i, FXY_i, FY_j, FY_{j+1} are exemplary functions satisfying the above conditions.

In consequence of the extraction of data by applying window

functions, the output of the tile decomposition portion 101 includes pixels of a tile ij plus peripheral pixels weighted with the window function values.

An image decoding device for decoding coded data from the image coding device of the embodiment 1 will be now described as an embodiment 3 of the present invention. Figure 13 is a block diagram of the image decoding device according to the embodiment 3.

The image decoding device receives coded data from the image coding device described as the embodiment 1 of the present invention. A management data separating portion 111 takes out information for managing tiles and subbands from the received coded data.

A coded data extracting portion 112 selectively extracts coded data of necessary tile and subbands according to the user's request. In the exemplary bit stream shown in Fig. 10, the management information is found in the header and the tile header.

The extracted coded information is entropy-decoded by an entropy decoding portion 113 and inversely quantized by an inverse quantizing portion 114 to produce wavelet-transform coefficients corresponding to the tile to be decoded.

The wavelet-transform coefficients are inversely transformed by an inverse wavelet transform portion 115 to produce a decoded image of the objective tile. The entropy-decoding portion 113, inverse quantizing portion 114

and inverse wavelet-transform portion 115 compose a so-called wavelet-transform decoding portion 116.

A tile combining portion 117 combines together decoded tiles according to the tile managing information to generate a decoded image of the desired area or at a desired resolution.

The decoding process with the bit stream shown in Fig. 10 is as follows. To decode a low-resolution entire image (all tiles), coded data (1-a, 2-a, …, i-a, …), which correspond to low-resolution subbands, are decoded in order in respective tile by the wavelet-transform decoding portion 116 according to the tile with referring to subband information included in each tile header.

The low-resolution decoded tiles are then combined by the tile-combining portion 117, thereby a whole low-resolution image is reproduced.

From the low-resolution decoded image, a particular tile "i" can also be reproduced in an enlarged scale with the highest resolution by decoding all the coded information of the i-th tile which correspond to the tile image "i".

Namely, coded information i-b extracted and decoded together with already extracted coded information i-a to obtain the desired decoded image. It is, of-course, possible to reproduce a high-resolution decoded image of all areas by decoding all coded information (all tiles including all subbands).

Thus, the image decoding device can easily decode any

resolution image and/or any tile (partial) image can be easily decoded according to the user's request.

An image decoding device according to another embodiment 4 of the present invention is as follows:

Coded data is input from the image coding device according to the embodiment 2 of the present invention. This image decoding device is similar in construction to the embodiment 3 shown in Fig. 13 and differs from the latter by the operation of the tile-combining portion 117, which will be described below with reference to Fig. 14.

In the image coding device according to the embodiment 2, pixels of each tile have been encoded together with pixels at its periphery. Therefore, data of a tile decoded in a wavelet-transform decoding portion 116 of this image decoding device is larger than an actual tile.

In Fig. 14, a tile is composed of 2 x 2 pixels and the data size of a decoded tile is of 4 x 4 pixels. In this case, decoded data of a tile ij has an area shaded in Fig. 14, which overlaps neighbors each by one pixel width.

The tile-combining portion 117 determines a pixel value for each overlap by adding together decoded data thereat when linking the decoded tiles. For example, the value of a pixel "a" in Fig. 14 is calculated as follows:

$$a(i-1,j-1)+a(i,j-1)+a(i-1,j)+a(i,j)$$

where $a(i,j)$ represents decoded data of the tile ij at the position of its pixel "a".

An image coding device according to another embodiment 5 of the present invention will be described with reference to Fig. 15 showing its construction.

This image coding device differs from the image coding device (embodiment 1) of Fig. 8 by the fact that it does not unconditionally conduct extrapolation of data at the periphery of an objective tile and utilizes another tile adjacent to the tile if such exists.

Like the embodiment 1, this image coding device decomposes an original image into tiles as shown in Fig. 16A at its tile decomposition portion 121 shown in Fig. 15. The image coding device further processes a tile "i" of the image as follows: In a wavelet-transform coding portion 123, image data of the tile "i" is wavelet-transformed through a wavelet-transform filter. In this case, if the filter extrudes from the tile "i" into neighboring tiles and covers part of pixels contained in the neighbors, image data of those pixels in the neighbors are also wavelet-transformed together with the image data of the objective tile "i" by the filter.

Referring to Fig. 16, the objective tile "i" of Fig. 16A is extended by adding necessary shaded parts of neighboring tiles a-h as shown in Fig. 16B and then wavelet-transformed.

An adjacent pixel adding portion 122 realizes the above process by recognizing neighboring tiles around the objective tile according to the tile decomposition information and by adding necessary pixels if the neighbors exist.

In the shown case, the adjacent pixel adding portion 122 adds to the objective tile "i" all neighboring pixels existing around there and outputs an increased volume of image data to a wavelet transform portion 123. The wavelet transform portion 123 must therefore transform a larger image area data as compared with the wavelet transform portion 102 of the embodiment 1 that transforms a single tile image.

With an increased image data to be transformed, the image coding device requires an enlarged working area for processing the data, resulting in increasing the cost of the device and decreasing the operating speed. Therefore, it is desirable to use another mode for reducing the size of data to be transformed by the wavelet-transform portion.

This mode is such that the additional adjacent area to be added by the peripheral pixel adding portion 122 to an objective tile area is limited to one direction "x" or "y" as shown in Fig. 16C or 16D to reduce the image data to be input to the wavelet transform portion 123.

For example, in case of Fig. 16C, an objective tile is provided with necessary pixels from upper and lower neighboring tiles if they exist. The right and left sides of the objective tile are treated by generating mirror images by folding the inside image of the tile. The case of Fig. 16D differs the above case of Fig. 16C by adding pixels from the right and left neighbors and generating mirror images for its top and bottom sides.

There are two alternative methods for performing the wavelet transform of the image data of the objective tile. One method is to recursively discompose any of the tile of Figs. 16B, 16C and 16D. The other method is to selectively apply any of the above three pixel-addition modes (Figs. 16B, 16C and 16D) for each subband.

The wavelet transform portion 123 generates wavelet transform coefficients of pixels included within the objective tile "i" using only for calculation purpose of wavelet transform coefficients of the pixels added thereto by the peripheral pixel adding portion 122.

A quantizing portion 124 quantizes the wavelet transform coefficients and an entropy coding portion 125 performs entropy encoding of the quantized coefficients to obtain coded information of the objective tile "i". The wavelet transform portion 123, quantizing portion 124 and entropy-coding portion 125 composes a so-called wavelet transform coding portion 126.

On the other hands, a management information generating portion 127 receives spatial-tile-position information from the tile decomposition portion 121 and subband information from the wavelet transform coding portion 126 and generates management information for managing and identifying tiles and subbands. The management information is used by a coded-data integrating portion 128.

The coded data integrating portion 128 rearranges and integrates coded information outputted from the entropy coding

portion 125 according to the management information outputted from the management portion 127 and then adds the management information to a bit stream to generate a final coded data as shown for example in Fig. 10.

An image coding device according to still another embodiment 6 of the present invention will be described below:

This image coding device is similar in construction to the device of the embodiment 5 described above with reference to Fig. 15 but differs from the latter only by the operation of its peripheral-pixel adding portion 122. The operation of the peripheral-pixel adding potion 122 is described below with reference to Fig. 17.

An objective tile "i" in Fig. 17 is now processed by way of example as follows:

In the embodiment 5, the peripheral-pixel-adding portion 122 added to a tile "i" all pixels necessary for calculating wavelet-transform coefficients for pixels in the objective tile, that is, pixels in areas covered by a filter extending from the objective tile. The adjacent pixel areas are shown as shaded in Fig. 17.

Since distant pixels have a small effect on wavelet transform coefficients in a tile "i", the embodiment 6 adds a result of multiplying peripheral pixels by a suitable weighing function to the tile "i" to reduce the number of pixels to be attached, i.e., lighten the computation work load.

The weighting function is 1 for each pixel near the tile

"i" and has a distance-depending value approaching to zero as a distance from the tile "i" increases. In Fig. 17, there is an example of a weighting function. Pixels multiplied by the weighting function and actually added to the objective tile compose an effective pixel area mesh-dotted in Fig. 17. A peripheral pixel area shown as shaded only in Fig. 17 is necessary for wavelet transform calculation but is not added because its weighted value is zero.

Alternatively, a stepwise weighting function may be applied, which is given 1 for each pixel within a specified distance from the tile "i" and 0 for all pixels existing over the specified distance.

Another image coding device is described as an embodiment 7 of the present invention. Figure 18 is a block diagram of an image coding device according to the embodiment 7.

This image coding device differs from the embodiment 1 of Fig. 8 and the embodiment 5 of fig. 5 by the fact that an original image is entirely wavelet-transformed by a wavelet transform portion 131 and, then, wavelet transform coefficients outputted from the wavelet transform portion 131 are rearranged per tile to compose respective tiles.

In Fig. 18, an original image before tiling is wavelet-transformed by a wavelet transform portion 131. A tile composing portion 132 composes tiles by rearranging wavelet transform coefficients so that a tile is composed of coefficients spatially matching the same tile.

Figure 19A shows an example of subbands obtained by wavelet transform portion 131. In the shown case, a coefficient b0 in the lowest frequency subband spatially correlates with other subband coefficients b1, b2, b3, b4, b5, b6, b7, b8 and b9.

Where b1-b3 consist each of 1x1 coefficient, b4-b6 consist each of 2x2 coefficients and b7-b9 consist each of 4x4 coefficients. These coefficients b0-b9 are taken out of the respective subbands and then arranged to compose a single tile as shown in Fig. 19B. Likewise, all other wavelet transform coefficients are arranged to compose respective tiles. This results in obtaining the same result as in the embodiment 5 whereby an original image is first decomposed into portion tiles and then wavelet transformed.

b0 is not necessarily a single coefficient, but it may be a block composed of k x 1 coefficient.

In this case, b1-b3 consist each of k x 1, b4-b6 consist each of 2k x 21 and b7-b9 consist each of 4k x 41 coefficients.

Wavelet transform coefficients organized per tile are outputted from the wavelet transform portion 132. They are quantized by a quantizing portion 133 and entropy-encoded by an entropy-coding portion 134, thus coded information is generated.

On the other hand, a management-information generating portion 136 generates management information necessary for managing and identifying tiles and subbands using spatial-tile-location information from the tile composing portion 132

and subband-location information from the wavelet transform coding portion 135. The management information is used by a coded-information integrating portion 137.

The coded information integrating portion 137 receives the management information from the management information generating portion 136 and the coded information from the entropy-coding portion 134 and it arranges and combines the entropy coded information and adds management information in a bit stream of the coded data, thus generating finally coded data as shown in Fig. 10.

Although the tile-composing portion 132 is installed before the quantizing portion 133 in this embodiment, it is not limited to this arrangement and may be placed after the quantizing portion 133.

An image decoding device for decoding data encoded by any one of the above-described image coding devices (embodiment 5 to 7) is now described below as an embodiment 8 of the present invention. Figure 20 is a block diagram showing the construction of the image decoding device according to the embodiment 8. The decoding device receives coded data encoded by any one of the image coding devices described above as embodiments 5 to 7.

Referring to Fig. 20, the image decoding device separately takes out tile-decomposition management information and subband-management information from the input coded-data stream by a management information separating portion 141 and

selectively extracts a necessary part of the coded information meeting the user's demand by a coded data extracting portion 142 according to the management information. Namely, the coded data corresponding to a necessary objective tile(s) having a necessary resolution is extracted by the coded data extracting portion 142.

The extracted coded information is entropy-decoded by an entropy decoding portion 143 and inversely quantized by an inverse quantizing portion 144. Thus, wavelet transform coefficients corresponding to an objective tile to be decoded are now obtained.

The wavelet transform coefficients inversely transformed by an inverse wavelet transform portion 145, thereby a decoded image including peripheral pixels data is produced. The entropy coding portion 143, the inverse quantizing portion 144 and the inverse wavelet transform portion 145 compose a so-called inverse wavelet transform decoding portion 146.

A tile combining portion 147 integrates groups of the decoded tiles according to the management information from the management information-separating portion 141. In this case, a completely decoded image is reproduced with overlaps of decoded tile images at each spatially overlapped portion.

Namely, the embodiment 2 described above with reference to Fig. 12 performed wavelet transform of each tile with adjacent pixels attached thereto. The embodiment 5 uses adjacent pixels in performing wavelet transform of each tile

as shown in Fig. 16B. Likewise, the embodiment 6 described with reference to Fig. 17 also uses peripheral pixels in wavelet transform of each tile.

In the image coding device according to the embodiment 7, the process using adjacent pixels is not clearly described but the wavelet transform of a whole original image has been done including the processing theoretically equivalent to that made in the embodiment 5.

Therefore, data of peripheral pixels is produced when each tile image is decoded by the wavelet transform decoding portion 146 in Fig. 20 and the decoded adjacent pixels are superposed on respective neighboring tiles by the tile combining portion 147. The superposition of one pixel on another is achieved by additive operation on the pixels.

Another image decoding device is described below as an embodiment 9 of the present invention. Like the above embodiment 8, the input to this embodiment 9 is coded data encoded by any one of the image coding devices being the embodiments 5 to 7. Figure 21 is a block diagram showing the construction of the image coding device according to the embodiment 9.

Referring to Fig. 21, a management information separating portion 151 separately takes out tile-division management information and subband management information from the input coded-data stream, and a coded data extracting portion 152 selectively extracts a necessary part of the coded information

meeting the user's demand according to the management information. Namely, the coded data corresponding to a necessary objective tile(s) having a necessary resolution is extracted by the coded data extracted portion 152.

The extracted coded information is entropy-decoded for each tile by an entropy-decoding portion 153 and inversely quantized by an inverse quantizing portion 154. Wavelet transform coefficients corresponding to an objective tile to be decoded are thus obtained. A wavelet transform coefficient rearranging portion 155 rearranges the wavelet transform coefficients into the state in which they were placed before tile-by-tile arrangement.

Namely, the wavelet transform coefficients divided per tile as shown in Fig. 19B are rearranged in the state shown in Fig. 19A. After completion of processing on all tiles, all wavelet transform coefficients of Fig. 19A are obtained.

The rearranged wavelet transform-coefficients can be decoded at a time by inverse transformation. Namely, the coefficients are inversely transformed by an inverse wavelet transform portion 156, thereby a whole decoded image is reproduced.

The entropy coding portion 153, the inverse quantizing portion 154 and the inverse wavelet transform portion 156 compose a so-called inverse wavelet transform decoding portion 157. Although the wavelet transform coefficient rearranging portion 155 is installed after the inverse quantizing portion

154 in this embodiment, it is not limited to this arrangement and may be placed before the inverse quantizing portion 154.

An image coding device is described below as an embodiment 10 of the present invention. Figure 22E is a block diagram of a portion of this embodiment, which responds to the wavelet transform portion (102 in Fig. 8, 123 in Fig. 15) of the image coding devices according to the embodiments 1, 2, 5 and 6.

Referring to Fig. 22E, a memory 162 is used for storing wavelet transform coefficients divided into subbands by a wavelet transform portion 161. In this case, the memory 162 stores only wavelet transform coefficients corresponding to a tile being currently processed by the wavelet transform portion 161. The processed data are transferred to a quantizing portion (103 in Fig. 8, 124 in Fig. 15) following the wavelet transform portion 161.

Therefore, the memory 162 has no need to store all data for a whole image and is sufficient to store such an amount of data necessary for processing only one tile.

Namely, if wavelet-transformation without tile decomposition is applied to a whole image as shown in Fig. 22A, it is necessary to store all wavelet transform coefficients (Fig. 22B) outputted from the wavelet transform portion 161. In contrast to the above, the decomposition of an image into tiles as shown in Fig. 22C enables the coding device to use a memory for storing only wavelet transform coefficients corresponding to a small image of Fig. 22D, thus realizing a

considerable saving of the memory capacity.

The same effect can be realized in an image decoding device. An image decoding device is described below as another embodiment 11 of the present invention. Figure 23E is a block diagram, which corresponds to the inverse wavelet transform portion (115 in Fig. 13, 145 in Fig. 20) of the image decoding devices described before as the embodiments 3, 4 and 8.

Referring to Fig. 23E, a memory 171 stores wavelet transform coefficients necessary for decoding one tile and an inverse wavelet transform portion 172 performs the composition of subbands.

An image that must be decoded is assumed to be that shown in Fig. 23B. When performing the wavelet transform of the image without decomposition into tiles, it is necessary to store all wavelet transform coefficients as shown in Fig. 23A. On the contrary, when decoding an image decomposed into tiles as shown in Fig. 23D, the image decoding device can operate using a memory 171 storing the limited number of wavelet transform coefficients as shown in Fig. 23C. The necessary memory capacity can be considerably saved.

All the above-described embodiments can be provided with a plurality of subband-decomposition filters that are adaptively switched over one another to use in the process of wavelet transform coding.

The subband decomposition filters mean low-pass filters and high-pass filters for decomposing an image into subbands

as described before for the prior art devices. The subband decomposition process is iterated for wavelet transformation. Filters to be used for this purpose are of various types having different numbers of taps and different coefficient values.

Accordingly, it is desirable to selectively apply suitable one of filters to each subband-decomposition because this enables the coding device to change a necessary amount of adjacent pixels for an objective image by applying a suitable filter for a current subband. Optimal wavelet transformation of an image may be achieved by finding a reasonable compromise between the processing data amount and the image quality.

In image decoding devices responding to such image coding devices, each of subband composition filters responding to respective subband decomposition filters used for wavelet transformation are selectively used for each of subbands to be combined through inverse wavelet transformation.

An image coding device is described below as another embodiment 12 of the present invention. In the embodiment 12, an input image can be encoded by one of plural predetermined coding methods.

Figure 24 is a block diagram showing an exemplary image coding device according to the embodiment 12. This embodiment 12 performs the image coding by switching the coding mode from the method of the embodiment 1 to the method of the embodiment 7 or vice versa.

Referring to Fig. 24, a tile wavelet-coding portion 201

performs wavelet encoding of the input image on a tile-by-tile basis and outputs coded information. This tile wavelet coding portion 201 also outputs tile-decomposition information, subband information and flag information.

A tile-management-information generating portion 203 receives the tile-decomposition information, the subband information and the flag information, and it prepares and provides management information including a combination of the above inputs. A coded data integration portion 107 outputs encoded data which combine the coded information and the management information.

In the tile wavelet-coding portion 201, an input original image is decomposed into tiles by the tile decomposition portion 101 and the decomposed image (tiles) is input to a terminal 0 of a first switch 204. The original image is input to a terminal 1 of the first switch 204. Either of two images through the switch 204 is input to a wavelet transform coding portion 207.

The wavelet transform coding portion 207 performs wavelet encoding of the input image. The output of a first wavelet transform portion 208 is input to a quantizing portion 103 through a second switch 205 or to the quantizing portion 103 through a tile-composing portion 132.

The operation of the first wavelet transform portion 208 is similar to the wavelet transform portion 102 of the embodiment 1 described with reference to Fig. 8. So, the portion

is not further described.

A flag generating portion 202 outputs a flag for selecting the encoding method of the embodiment 1 or the encoding method of the embodiment 7 and, at the same time, controls the first switch 204, second switch 205 and third switch 206.

When the switches 204, 205, 206 are connected to terminals 0, the coding device performs the coding operation in the same way as the embodiment 1 does. With the switches connected to terminals 1, the coding device conducts the coding operation in the same way as the embodiment 7 does.

The operation of a tile-composing portion 132 is the same as that of the embodiment 7 described before with reference to Fig. 18. Further description is omitted.

As described above, the present embodiment can encode an input image on a tile-by-tile basis and selectively switches the coding system to the method of the embodiment 1 featured by simple image-by-image processing or the method of the embodiment 7 featured by coding of each tile with no distortion at the boundary thereof.

Figure 25 is a block diagram of another exemplary image coding device according to the embodiment 12. In this coding device, coding can be conducted by selectively applying the method of the embodiment 1 and the method of the embodiment 5.

Referring to Fig. 25, the image coding device differs from the former type by omitting the tile composing portion 132 (Fig.

24) relating to the embodiment 7 and adding an adjacent pixel adding portion 122 relating to the embodiment 5 and a second wavelet transform portion 305 with a selector switch. Since the operation of the components of this coding device except tile wavelet-transform coding portions 301 and 302 (Fig. 25) are similar to those of the image coding device of Fig. 24, so further description is omitted.

The wavelet transform coding portion 302 performs wavelet coding of an input image and outputs coded information. This device has two inputs: one is connected to a first wavelet transforming portion 208 and the other is connected to a second wavelet transforming portion 305.

When an image is input to the first wavelet transform coding portion 208, the wavelet transform coding portion 302 performs the same operation as the wavelet transform coding portion 207 of Fig. 24 does. When an image is input to the second wavelet transform portion 305, the wavelet transform coding portion 302 performs the same operation as the wavelet transform coding portion 126 of Fig. 15 does, since the operation of the first wavelet transform portion 305 is similar to that of the wavelet transform portion 123 of Fig. 15.

In tile wavelet coding portion 301, the input image is decomposed into tiles and transferred to a first switch 303. On the other hand, the decomposed tile images with adjacent pixels are inputted to a second switch 304. A flag-generating portion 306 selects the use of the first wavelet-transform

portion 208 or the second wavelet-transform portion 305 in the wavelet transform coding portion and outputs a flag indicating the selection made.

At the same time, the above selection causes the first switch 303 or the second switch 304 to turn ON. Once the first switch was turned ON, the decomposed image is inputted to the first wavelet transform portion 208 whereby the same coding process as made in the embodiment 1 is performed. Once the second switch 304 was selected, the image decomposed into tiles with peripheral pixels is inputted to the second wavelet-transform portion 305 whereby the coding process of the embodiment 5 is performed.

Thus, the image coding device can process an input image on a tile-by-tile basis and can encode the image by selectively applying the simple coding method of the embodiment 1 or the tile-boundary distortionless coding method of the embodiment 5, (by which each tile can be encoded without distortion of its boundary).

Another exemplary image coding device according to the embodiment 12 is shown in Fig. 26, which is capable of selectively applying three different coding modes: methods of the embodiments 1, 5 and 7.

As shown in Fig. 26, this image coding device differs in construction from the image coding device of Fig. 25 by including a tile composing portion 132 and switching circuitry for realizing the coding mode of the embodiment 7. The operation

of this device excepting a tile wavelet transform coding portion 401 and a wavelet transform coding portion 407 is similar to that of the device of Fig. 24, so further description of the portions is omitted.

The wavelet transform coding portion 407 performs wavelet encoding of an input image and outputs coded information of the image. The output of a first wavelet transform portion 308 is inputted to a quantizing portion 103 through a third switch 405 or further through a tile-composing portion 132. The output of a second wavelet-transform portion 305 is inputted directly to the quantizing portion 103.

In the tile wavelet-coding portion 401, the input image is inputted directly to a terminal 0 of the first switch 403. Alternatively, it is decomposed into tiles and then inputted to a terminal 1 of the first switch 403, or it is discomposed into tiles each including necessary peripheral pixels and then inputted to a terminal 2 of the switch 403.

These images are transferred to a first wavelet-transforming portion 308 or a second wavelet-transforming portion 305 through the second switch 404. The image data is quantized in a quantizing portion 103 and encoded in an entropy-coding portion 104 wherefrom coded information is outputted.

A flag generating portion 402 controls the first, second, third and fourth switches 403, 404, 405, 406 to selectively switch the coding modes 0, 1 and 2. The mode numbers are

indicated at terminals of the switches 403, 404, 405 and 406 respectively in Fig. 26.

When the first switch 403 is connected to the terminal 0, all remaining switches 404, 405 and 406 are also connected to their terminals 0. With the switches 403-406 connected to the terminals 0, the image coding device encodes the input image by applying the coding mode of the embodiment 7.

When the switches 403-406 are all connected to their terminals 1, the image coding device encodes the input image by applying the coding mode of the embodiment 1. When the first, second and fourth switches 403, 404, 406 are connected to their terminal 2, the image coding device encodes the input image by using the coding mode of the embodiment 5.

Thus, the image coding device can process an input image on a tile-by-tile basis and can also encode the image by selectively applying one of three coding modes: the simple tile-image-coding method of the embodiment 1, the tile-boundary distortionless coding method of the embodiment 5 or 7, (by which each tile can be encoded without distortion of its boundary).

An image decoding device according to another embodiment 13 of the present invention is described below. The input to this device is coded data encoded by the image coding device according to the embodiment 12 of the present invention. The input data is decoded by this device by applying one of predetermined modes of decoding.

Fig. 27 is a block diagram of an exemplary image decoding device according to the embodiment 13, which is capable of decoding coded data generated by the image decoding device (embodiment 13) by selectively applying two coding methods used in the embodiments 1 and 7.

Referring to Fig. 27, coded information and management information are separated each other at a management-information separating portion 111 and inputted to a tile wavelet decoding portion 501 that in turn performs tile-by-tile decoding of the coded data using the management information and outputs a decoded image.

The coded data is inputted to a wavelet transform decoding portion 502 whereby it is wavelet-decoded. The image decoded by the wavelet transform decoding portion 502 is outputted directly by a second switch 504 or outputted through a tile-combining portion 117.

In the wavelet transform decoding portion 502, the output of an inverse quantizing portion 114 is applied to a first inverse wavelet-transform portion 506 through a first switch 503 or to the first inverse wavelet transform portion 506 through a wavelet-coefficient rearranging portion 155.

The operation of the first inverse wavelet-transform portion 506 is similar to that of the inverse wavelet-transforming portion 115 in the embodiment 3, so further description is omitted.

A flag-generating portion 505 extracts flags for

controlling the first switch 503 and the second switch 504 from the management information. With the switches 503 and 504 connected to their terminals 0, the image decoding device performs the same decoding operation that the embodiment 3 does. With the switches 503 and 504 connected to the terminals 1, the image decoding device performs the same decoding operation that the embodiment 9 does.

The operation of a tile-combining portion 117 is similar to that of the same portion of the embodiment 3 described with reference to Fig. 13, so further description is omitted.

The image decoding device according to the embodiment 13 can process coded image data on a tile-by-tile basis and can also decode the image by selectively applying two decoding modes: the simple tile-image-decoding method of the embodiment 3 and the tile-boundary distortionless decoding method of the embodiment 9, (by which each tile can be encoded without distortion of its boundary).

Figure 28 is a block diagram of another exemplary image decoding device according to the embodiment 13 of the present invention, which is capable of decoding image data encoded by selectively applying two coding methods of the embodiments 1 and 5.

The operation of this device except a tile wavelet transform decoding portion 601 and a wavelet transform decoding portion 602 (Fig. 28) are similar to that of the device of Fig. 27, so further description of the like portions is omitted.

The wavelet transform decoding portion 602 performs wavelet decoding of input coded information. The output of an inverse quantizing portion 114 through a first switch 604 is inputted to a first inverse wavelet transform portion 506 or a second inverse transforming portion 603.

The output of the first inverse wavelet transform portion 506 is transferred to a tile composing portion 117 and the output of the second inverse wavelet transform portion 603 is transferred to a tile integrating portion 147.

The operation of the second inverse wavelet transforming portion 603 is similar to the inverse wavelet transform portion 145 of the embodiment 8 described with reference to Fig. 20, so further description is omitted.

In the tile wavelet decoding portion 601, the wavelet transform decoding portion 602 performs wavelet decoding of the coded information and outputs the decoded information to the tile composing portion 117 or the tile integrating portion 147. A decoded image is now reproduced.

On the other hand, a flag-generating portion 605 extracts a flag from the management information and controls the operation of a first switch 604 by the extracted flag. With the switch 604 connected to its terminal 0, the image decoding device performs the same decoding operation that the embodiment 3 does. With the switch 604 connected to its terminal 1, the image decoding device performs the same decoding operation that the embodiment 8 does.

Thus, the image decoding device according to the embodiment 13 can process coded image data on a tile-by-tile basis and can also decode the image by selectively applying two decoding modes: the simple image-decoding method of the embodiment 3 and the tile-boundary distortionless decoding method of the embodiment 8, (by which each tile can be encoded without distortion of its boundary).

Figure 29 is a block diagram of a further exemplary image decoding device according to the embodiment 13 of the present invention, which is capable of decoding image data encoded by selectively applying three coding methods of the embodiments 1, 5 and 7.

Referring to Fig. 29, this image decoding device differs from the image decoding device of Fig. 28 by the provision of a wavelet-coefficient rearranging portion 155 and related switch circuitry. Since the operation of this device excepting a tile wavelet transform decoding portion 701 and a wavelet transform decoding portion 702 (Fig. 29) is similar to that of the device of Fig. 27, so further description of the like portions is omitted.

The wavelet transform decoding portion 702 performs wavelet decoding of input coded information. The output of an inverse quantizing portion 114 is inputted to a first inverse wavelet transform decoding portion 506 through a terminal 0 of a first switch or a wavelet coefficient rearranging portion 155 through a terminal 1 of the first switch 703. Alternatively,

it is transferred to a second inverse transforming portion 603 through a terminal 2 of the first switch 703.

The output of the first inverse wavelet-transforming portion 506 is transferred to a tile-composing portion 117 through a second switch 704 or a decoded image is directly outputted. The output of the second inverse wavelet-transform portion 603 is transferred to a tile-integrating portion 147. The operation of other components is similar to that of like components of the wavelet-decoding portion 602 (Fig. 28), so further description is omitted.

In the tile wavelet decoding portion 701, a flag extracting portion 705 extracts flags for controlling the first switch 703 and the second switch 704 from the management information. The remaining management information is inputted to the tile-composing portion 117 and the tile-integrating portion 147.

With the switches 703 and 704 connected to its terminal 0, the image decoding device performs the same decoding operation that the embodiment 3 does. With the switches 703 and 704 connected to its terminal 1, the image decoding device performs the same decoding operation that the embodiment 9 does. When the first switch 703 is connected to its terminal 2, the device performs, the same decoding operation that the embodiment 8 does irrespective of the position of the second switch 704.

Thus, the image decoding device according to the embodiment

13 can process coded image data on a tile-by-tile basis and can also decode the image by selectively applying three decoding modes: the simple tile-image-decoding method of the embodiment 3 and the tile-boundary distortionless decoding method of the embodiments 8 and 9, (by which each tile can be encoded without distortion of its boundary).

An image coding device is described below as an embodiment 14 of the present invention. In this embodiment, tile management information including information for identifying (distinguishing) tiles is utilized to realize high-speed decoding of any objective tile.

Figure 30 is a block diagram showing an exemplary image coding device according to the embodiment 14. Referring to Fig. 30, a tile wavelet-coding portion 801 performs wavelet encoding of an input original image on a tile-by-tile basis, and it generates coded information and management information such as tile-decomposition information, flag information and subband information.

An ID generating portion 802 generates ID information for identifying each tile. Management information generating portion 803 generates management information by combining the management information with the ID information. A coded-data combing portion 804 generates coded data by combining the coded information with the management information and placing a tile-information start code at the head of information of each tile.

Figure 31A shows an example of the coded data format that defines each tile information consisting of a tile-information start code, management information (tile header) and coded data. The tile wavelet-coding portion 801 can be commonly used for image coding devices according to embodiments 1, 2, 5, 6, 7, 10, 12 and 14.

To distinguish tiles into which an original image was decomposed, ID numbers (e.g., 1, 2, …) are assigned to tiles arranged in a sequence from the top left as shown Fig. 31. Tiles having ID numbers can be coded in any order and rearranged after coding. Moreover, the ID generating portion 802 may be omitted if the order of tiles to be encoded is predetermined.

The location of each tile can be found by its start code or by its data size (coded information plus tile header).

Figure 32 is a block diagram of another exemplary image coding device according to the embodiment 14. This image coding device differs from the device of Fig. 30 only by the provision of a data-size calculating portion 811, so the portions other than the calculating portion 811 and the management-information generating portion 812 are omitted from the scope of further description.

Referring to Fig. 32, the data-size calculating portion 811 calculates a size of coded data for each tile and outputs the calculation result. The management information generating portion 812 prepares management information consisting of management information, ID information and a coded tile-data

size.

Figure 31B shows an example of a coded information format in each tile, a coded tile-data size is placed at the head, and following other, management information (tile header) and coded information. The coded tile-data size is not necessarily placed at the top of each tile field. Alternatively, data-size values for all tiles may be placed together at the top of the format.

Figure 33 is a block diagram of another exemplary image coding device according to the embodiment 14. This image coding device differs from the device of Fig. 32 only by the provision of a coded-data rearranging portion 821, so the portions other than the calculating portion 821 and the management-information generating portion are omitted from the scope of further description.

Referring to Fig. 33, the coded-data rearranging portion 821 extracts a coded data size for each tile from coded data prepared by a code-data combing portion 804 and puts the data-size value at the head of coded data and arranges other remaining data in a given order, then outputs a sequence of the coded data.

In case of an exemplary coded-data format shown in Fig. 31C, the location of any objective tile can be easily determined by summing data-size values from the top tile to a just preceding one.

Figure 34 shows another exemplary image coding device

according the embodiment 14, which can realize the same effects as the above and which differs from the above device of Fig. 32 by the provision of a coded data storaging portion 831 and a management information storaging portion 832. Therefore, all components other than the coded-data storing portion 831, the management information storaging portion 832 and a coded data combining portion 833 are omitted from further description.

Referring to Fig. 34, coded information outputted from a tile wavelet coding portion 801 are temporally stored in the coded-data storaging portion 831. The management information storaging portion 832 stores tile management information generated by the management-information generating portion 812. It extracts tile-size data from the tile-management-information, sends the data to the coded data combining portion 833 and then outputs the remaining management information.

First, the coded data-combining portion 833 outputs all the data size values for all tiles and then outputs remaining management information combined with coded information.

According to the embodiment 14 of the present invention, it is possible to immediately retrieve coded information of any desirable tile to be decoded.

An image decoding device is described below as another embodiment 15 of the present invention. Figure 35 is a block diagram of an image decoding device according to the embodiment 15, which is capable of decoding coded data encoded and supplied by the image coding device according to the embodiment 14.

Referring to Fig. 35, an objective-tile deciding portion 903 decides an ID of an objective tile to be decoded according to the user's request. A management-information separating portion 906 retrieves a start code indicating the head of the objective-tile coded information in a coded-data sequence and separates the objective tile management information from the objective-tile coded-information.

Based on the management information, a data skip control portion 902 decides whether the ID of the tile to be decoded matches the ID decided by the deciding portion 903. If two IDs match, the portion 902 turns on both a first switch 905 and a second switch 904. Consequently, a tile wavelet-decoding portion 901 can decode the selected tile only.

If the tile management information includes each tile-data size, the management-information separating portion 906 has no need to search tile-data heads and can find the location of the objective tile data head by skipping the unnecessary amount. The tile wavelet-decoding portion 901 can be commonly used in the image decoding devices according to the embodiments 3, 4, 8, 9, 11, 13 and 15.

According to the embodiment 15, it is possible to immediately retrieve and decode the coded data of the object tile by using only the tile head management information without decoding any other coded data.

An image coding device is now described below as another embodiment 16 of the present invention, which can provide coded

tile images that can be decoded immediately to reproduce a single objective tile image as well as adjacent tile images by using tile-management information including neighbors' information.

Figure 36A is a block diagram of an exemplary image coding device according to the embodiment 16. This device differs from the embodiment 14 of Fig. 30 by the addition of an adjacent tile ID deciding portion 841 and by the operation of a management-information generating portion 841. Other portions are similar to those of the embodiment 14 and omitted from the scope of further description.

A tile wavelet-coding portion 841 can be commonly used in the image coding devices of the embodiments 5, 6, 7, 10, 12 and 14.

Referring to Fig. 36A, the adjacent tile ID deciding portion 841 decides IDs of adjacent tiles necessary for decoding an objective tile according to tile decomposition information, flag information, subband information and tile IDs produced by an ID generating portion 802. A management-information generating portion 842 prepares management information containing tile decomposition information, flag information, subband information and tile ID with adjacent tiles IDs.

Since all adjacent tiles necessary for coding an objective tile are not necessarily given IDs, the number of adjacent IDs to be produced by the peripheral tile ID deciding portion 841

may be limited to, for example, two neighbors existing left above and left below the objective tile as shown in Fig. 36B.

In the coded data format of Fig. 31A, the management information (tile header) may include an objective tile ID and adjacent tiles' IDs.

Figure 37 is a block diagram of an exemplary image coding device according to the embodiment 16 of the present invention, which is intended to encode tile images that may be rapidly retrieved for decoding by using management information including each objective tile ID with neighbors' IDs. This image coding device is similar in construction to embodiment 14 of Fig. 34 but differs from the embodiment 14 by the absence of the management information storing portion 832 and by the presence of a data-size storing portion 853, relative position calculating portion 852 and information storing buffer 854.

The operation of this image coding device is similar to the embodiment 14 except the operation with the data-size storing portion 851, relative position calculating portion 852, information storaging buffer 854, management information generating portion 853 and ID generating portion 855. Therefore, like components are not described further.

Referring to Fig. 37, coded information outputted from a tile wavelet coding portion 801 are all stored in a coded data storaging buffer 831. Tile-decomposition information, flag information and subband information from the tile wavelet coding portion 801 are all stored in the information storaging

buffer 854. Tile-data-size values outputted from the data-size calculating portion 811 are all stored in the data-size storing portion 851.

The ID generating portion 855 outputs ID information to identify each tile and controls the information storing buffer 854, the data-size storing portion 851 and the coded data storaging buffer 831 to output information on a tile-by-tile basis. The data-size storing portion 851 receives a tile ID and outputs a data-size value of the tile specified by the received ID to the management information generating portion 853. It also provides the relative-position calculating portion 852 with the tile-data-size necessary for calculating positions of neighbors relative to the tile having the ID.

The relative-position calculating portion 852 calculates the positions of coded information of the adjacent tiles relative to an objective tile by using the data-sizes of the input tiles and outputs the calculation results. The management information generating portion 853 generates management information by using input information such as tile ID information, tile-decomposition information, flag information, subband information, tile-data-size values, relative positions of adjacent tiles, etc. It outputs the prepared management information to the coded data combining portion 2503.

The above system can produce coded data of tile images, which can be effectively decoded at a high speed without

decoding all coded data in such a way that coded data of an objective tile and necessary adjacent tiles may be retrieved and decode by decoding only management information located at the head of the decodable coded data.

An image decoding device is described below as another embodiment 19 of the present invention. Figure 38 is a block diagram of the image decoding device according to the embodiment 19, which is used for decoding coded data produced by the image coding device according to the embodiment 18. This device is similar to and differs from the embodiment 15 of Fig. 35 only by the addition of a buffer 911. All components other than the buffer 911 and a skip-and-read control portion 912 operate in the same way that like components of the embodiment 15. So, they are omitted from the scope of further description.

Referring to Fig. 38, input coded data is temporally stored in the buffer 911 wherefrom it is subsequently outputted later. The skip-and-read control portion 912 extracts an ID for an objective tile according to the input management information. When the extracted ID matches the ID of the objective tile or the ID of a related adjacent tile, this control portion 912 causes a first switch 905 and a second switch 904 to turn ON.

If the management information contains IDs of adjacent tiles necessary for decoding the objective tile, the control portion 912 controls the buffer storage 911 to output the coded data of the adjacent tiles. Consequently, the tile wavelet-decoding portion 901 can decode a specified tile and

necessary neighbors.

If the predetermined number (e.g., two dotted tiles in Fig. 36B) of peripheral IDs decoded in the management information is smaller than the number of necessary peripheral tiles (e.g., six unshaded neighbors in Fig. 36B), IDs of the remaining necessary neighbors are decided from the decoded IDs of the adjacent tiles.

The tile wavelet-decoding portion 901 can be commonly used in embodiments 8, 9, 11, 13 and 15.

The above system can immediately decode any objective tile and necessary adjacent tiles by decoding only the management information put at the head of the coded data. It has no need of decoding all the coded data.

THE POSSIBLE INDUSTRIAL APPLICATIONS

As described herein, following aspects are brought according to the present invention.

In one aspect of the present invention, an image coding device can independently encode each of tiles of an original image, thus providing coded tile images that can be separately treated thereafter. If any of coded tile must be further processed, it can be separately, processed and encoded again with no need of using adjacent pixels. Thus, simple independent encoding and decoding of image tiles is realized.

In another aspect of the present invention, an image decoding device can decode only a desirable coded tile image

with no need of decoding any other coded data, thereby minimizing the processing load.

In another aspect of the present invention, in spite of increasing of the coded-data size due to encoding an objective tile image including adjacent pixels, an image decoding device decodes the coded tile image by superposing adjacent pixel values on overlaps, suppressing possible boundary distortion of the tile image.

In still another aspect of the present invention, an image coding device can encode tile images using pixel information on neighboring tiles, achieving high efficiency of image encoding using the correlation between tiles. This can also suppress possible boundary distortion of the tile images.

In another aspect of the present invention, an image coding device can effectively encode a part (plural tiles) of a whole image by performing wavelet transform of only selected tiles, and its wavelet transform is very compact.

An image decoding device responding to the above can also realize compact inverse wavelet transform of coded tile images.

In a further aspect of the present invention, an image coding device can decide exclusion of distant pixels from the scope of adjacent pixels for calculation. This minimizes the number of filtering operations and wavelet-transform operations.

A whole image is wavelet transformed at a time and then wavelet transformed coefficients are rearranged to compose

respective tiles. This eliminates the need of iterating the wavelet-transform for each tile.

In another aspect of the present invention, an image decoding device can rearrange coded data (decomposed for each tile) corresponding to an objective tile and then perform inverse wavelet transform of the coded data at a time, thus eliminating the need of repeating inverse wavelet transform for each tile.

Conventional arts demand a large capacity of a memory for holding wavelet transformed coefficients to correspond to resolution of an original image. In contrast to the above, an image coding device according to one aspect of the present invention can use, irrespective of the original image size, a memory which can store only wavelet transform coefficients for capacity corresponds to the size of a tile or tiles for a tile or tiles being currently encoded. This can realize a considerable saving of memory capacity needed.

In another aspect of the present invention, an image decoding device can also use a memory having the capacity limited to a tile size for storing wavelet transform coefficients.

In a further aspect of the present invention, an image coding device can conduct wavelet transform by selectively applying plural suitable filters for decomposing an objective tile image into subbands, thus realizing optimal wavelet transform of the objective tile with the best balance between

the image quality and the processing load.

In a further aspect of the present invention, an image decoding device can conduct inverse wavelet transform by selectively applying plural suitable filters for composing subbands, which respond to the subband decomposing filters. Thus, the device realizes the optimal inverse wavelet transform of each tile to be decoded.

In a still further aspect of the present invention, an image decoding device can selectively apply two wavelet transform modes: one for each tile with or without adjacent pixels and the other for each image with or without adjacent pixels. Two modes can be selected in accordance with the input image quality to minimize the increase of transform operations and deterioration of the image quality.

In another aspect of the present invention, an image decoding device can easily retrieve coded information of an objective tile to be decoded by searching management information well organized for identifying every tile. Therefore, it can realize high-speed retrieval and effective decoding of only plural tiles necessary for reproducing an area (several tiles) of a whole image.

In still another aspect of the present invention, an image decoding device can easily retrieve coded information of an objective tile and coded information of adjacent tiles necessary for decoding the objective tile by using management information well organized for identifying every tile.

Therefore, only an area (several tiles) of a whole image can be rapidly reproduced by decoding only necessary tiles.

High efficient coding/decoding of image tiles using adjacent pixel information is also achieved by utilizing the effect of correlative effect of the pixels.

Amended claims

[The amendment was received on February 22, 1999, by the International Bureau. The original claims 1 to 19 were replaced with the amended claims 1 to 19.]

1. (Amended) An image coding device comprising:

a tile decomposition portion for decomposing image data into tiles each of N pixels x M pixels and outputting the N pixels x M pixels in the tile as an objective data to be coded for a corresponding each of the tiles;

a wavelet coding portion for extrapolating a predetermined data at the neighboring of the objective data input from the tile decomposition portion, decomposing each of the tiles into subbands and performing separate wavelet-encoding of each of the tiles;

a management information generating portion for generating management information necessary for independently decoding coded data of the subbands from the wavelet-coding portion on a tile-by-tile basis as well as on the subband-by-subband basis; and

a coded data integrating portion for attaching the management information to coded data.

2. (Amended) An image coding device as defined in claim 1, wherein the tile decomposition portion composes original image data into tiles each of the N pixels x M pixels and outputting, as the objective data to be coded corresponding

to said each of the tiles, a result of multiplying each of the tiles and neighboring pixel data by a predetermined two-dimensional window function.

3. (Amended) An image coding device comprising:

a tile decomposition portion for decomposing image data into tiles each of N pixels x M pixels and outputting the N x M pixels in the tile as an objective data to be coded for a corresponding each of the tiles;

a adjacent pixel adding portion for providing an objective tile to be coded with adjacent pixels necessary for wavelet transformation of the objective tile to be coded when such pixels exist at the neighboring thereof;

a wavelet coding portion for extrapolating a predetermined data when no pixel existing at the neighboring of the objective tile to be coded, decomposing each of the tiles into subbands and outputs only wavelet coefficients of the objective tile;

a management information generating portion for generating management information necessary for independently decoding coded data outputted from the wavelet coding portion on a tile-by-tile basis as well as on a subband-by-subband basis; and

a coded data integrating portion for attaching the management information to coded data.

4. (Amended) An image coding device as defined in claim 3, wherein the each adjacent pixel to be attached to the objective tile is multiplied by a weighting function according

to a distance from the objective tile, when each of the objective tiles is attached the adjacent pixel by the adjacent pixel adding portion.

5. (Amended) An image coding device comprising:

a wavelet coding portion for decomposing an image into subbands by extrapolating a predetermined data at the neighboring of the image, and performing wavelet encoding of the subbands;

a tile composing portion for reconstructing, from wavelet coefficient inputted from the wavelet coding portion, tiles each of N x M wavelet coefficients spatially responding to respective tiles to be entropy coded;

a management information generating portion for generating management information necessary for independently decoding coded data outputted from the wavelet coding portion on a tile-by-tile basis as well as on a subband-by-subband basis; and

a coded data integrating portion for attaching the management information to the coded data.

6. (Amended) An image coding device as defined in any of claims 1 to 4, wherein the wavelet coding portion is provided with a memory necessary for storing at least data for the tile.

7. (Amended) An image coding device as defined in any of claims 1 to 6, wherein the wavelet coding portion performs multiple times the subband decomposition process by selectively applying suitable filters for respective

subbands.

8. An image coding device having a combination of plural coding modes selectable from claims 1 to 7 and having a plurality of selectively applicable coding modes, which further includes a flag generator for generating flags indicating respective coding modes and a control portion for controlling the coding device in a mode specified by the flag generated by the flag generating portion, wherein the management information generating portion generates management information including the flags generated by the flag generating portion.

9. (Amended) An image coding device as defined in any of claims 1 to 8, wherein an ID generating portion for generating IDs for identifying respective tiles is further provided and the management information generating portion generates management information including the IDs generated by the ID generating portion.

10. (Amended) An image coding device as defined in any of claims 1 to 8, which further includes an ID generating portion for generating IDs for identifying respective tiles and a adjacent tile ID deciding portion for generating IDs of adjacent tiles around an objective tile to be coded by using ID information from the ID generating portion and tile information from the wavelet coding portion, wherein the management information generating portion generates management information including the IDs and the IDs of

adjacent tile.

11. (Amended) An image decoding device for receiving, at its input, coded information including: coded data of image data divided into tiles each containing N pixels x M pixels and separately wavelet-encoded; and management information for managing and identifying subbands generated by wavelet-encoding of the tiles and for selectively decoding an coded image corresponding to a necessary tile and subbands, comprising:

a management information separating portion for separating management information from an input coded data;

a coded data extracting portion for extracting coded data part corresponding to an objective tile and subbands according to the management information;

a wavelet decoding portion for performing wavelet decoding of the coded data extracted by the coded data extracting portion; and

a tile-combining portion for combining images decoded on a tile-by-tile basis into a desired decoded image.

12. (Amended) An image decoding device for receiving at its input a bit stream of coded information including: coded information of image data divided into tiles each containing N pixels x M pixels and separately wavelet-encoded after multiplying each tile data plus adjacent pixel data by a specified two-dimensional window function; tile-position information for specifying a location of each of the tiles in

the coded information bit-stream; and management information for managing and identifying subbands generated when wavelet-encoding of the tiles, and for decoding an coded image corresponding to a necessary tile and subbands, comprising:

a management information separating portion for separating management information from the input bit stream;

a coded data extracting portion for extracting coded data part corresponding to an objective tile and subbands according to the management information;

a wavelet decoding portion for conducting wavelet-decoding of the coded data extracted by the coded data extracting portion; and

a tile integrating portion for arranging wavelet decoded data at respective places on an original image and superposing image values at overlaps of neighboring tiles to integrate the tiles into a desired decoded image.

13. (Amended) An image decoding device for receiving, at its input, coded information including: coded information of image data divided into tiles, each of the tiles containing N pixels x M pixels and separately wavelet-encoded after attaching thereto adjacent pixels necessary for wavelet-transforming said tile when such pixels existing at the neighboring thereof; and management information necessary for decoding each tile and each subband; and for (selectively) decoding an coded image corresponding to a necessary tile and subbands, comprising:

a management information separating portion for separating management information from the input bit stream;

a coded data extracting portion for extracting coded data part corresponding to an objective tile, tiles existing around the objective tile and subbands according to the management information;

a wavelet decoding portion for conducting wavelet-decoding of the coded data extracted by the coded data extracting portion; and

a tile integrating portion for arranging wavelet-decoded data at respective places on an original image and superposing image values at overlaps of neighboring tales to integrate the tiles into a desired decoded image.

14. (Amended) An image decoding device for receiving input coded information including: coded information of an entropy-transformed into groups each of N wavelet coefficients x M wavelet coefficients spatially corresponding to a tile and entropy-encoded on a tile-by-tile basis; and management information for managing and identifying subbands generated when wavelet-encoding of the tiles, and for decoding an coded image corresponding to a necessary tile and subbands, comprising:

a management information separating portion for separating management information from the input bit stream;

a coded data extracting portion for extracting coded data part corresponding to an objective tile and subbands according

to the management information;

a wavelet decoding portion for conducting wavelet-decoding of the coded information extracted by the coded data extracting portion; and

a wavelet-coefficient rearranging portion for rearranging the wavelet-coefficients arranged per tile in the wavelet decoding portion to the initial order image divided into subbands, said subbands wavelet- before decomposition into tiles.

15. (Amended) An image decoding device as defined in any of claims 11 to 14, wherein the wavelet decoding portion includes a memory for storing data at least for the tile.

16. (Amended) An image decoding device as defined in any of claims 11 to 15, wherein the wavelet decoding portion repeats multiple times the subband composition with use of filters changeable every iteration.

17. (Amended) An image decoding device having a combination of plural decoding systems selectable from claims 11 to 16 and having plural decoding modes selectively applicable, which further includes:

a management information separating portion for separating management information necessary for decoding each tile and each subband from the input coded data;

a flag extracting portion for extracting from the management information a flag for specifying a decoding mode used for decoding the coded data from the management

information; and

a control portion for controlling the decoding device to be activated in a decoding mode corresponding to the extracted flag.

18. (Amended) An image decoding device as defined in any of claims 11 to 17, which further includes a control portion for controlling inputting of coded data to the wavelet decoding portion according to ID information so as to decode only a tile having a specified ID by the wavelet decoding portion.

19. (Amended) An image decoding device as defined in any of claims 11 to 17, which further includes a buffer memory for storing input coded data and a control portion for controlling the data from the buffer according to ID information and adjacent tile ID information in management information from the management information separating portion so that coded data only for an objective tile having a specified ID and related adjacent tiles having respective IDs is outputted from the buffer memory and inputted to the wavelet coding portion to decode only the specified tile and the adjacent tiles.

ABSTRACT

An image encoder/decoder by which a partial image is encoded easily with a resolution meeting the user's demand, the encoded amount of data is not increased and a necessary capacity of memory can be reduced. The image encoder has a tile decomposition portion (101) which divides image data into tiles of N pixels x M pixels, a wavelet transform coding portion (105) which extrapolates predetermined data at the peripheries of the tiles outputted from the tile decomposition portion (101) and performs subdivision to perform wavelet encoding, a management information generating portion (106) which generates information for managing the encoded data in order that the encoded data outputted from the wavelet transform coding portion (105) can be decoded for each tile and for each subband of the wavelet encoding, and an coded data integration portion (107) which links the encoded data encoded by wavelet encoding for each tile by using the output of the management information generating portion (106) and adds the managing information to the encoded data.

FIG.1

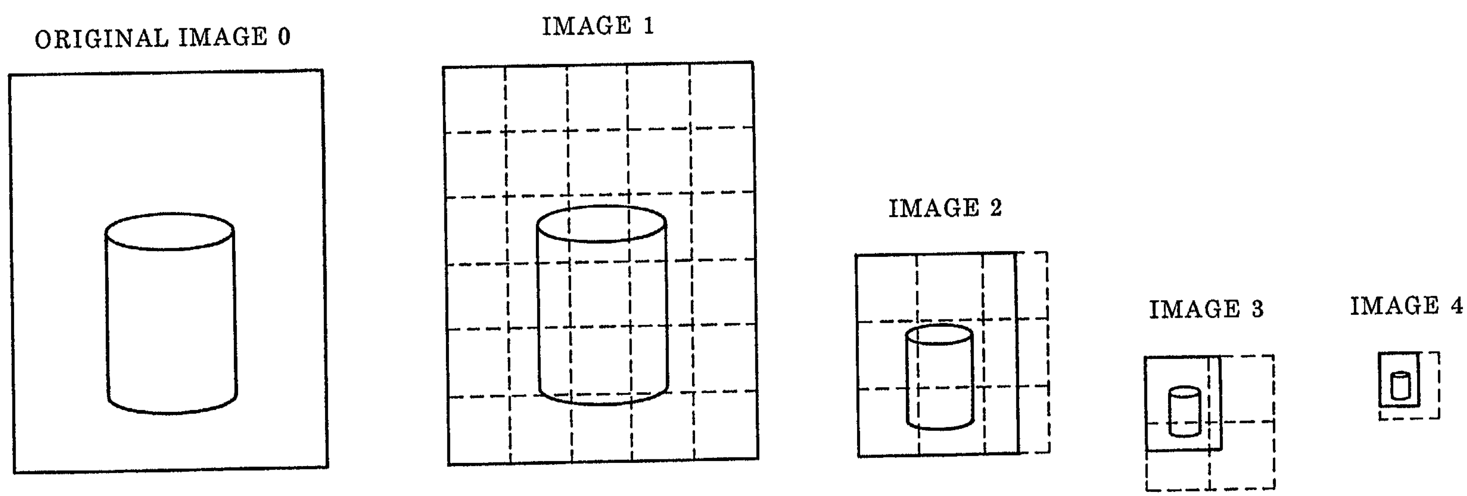
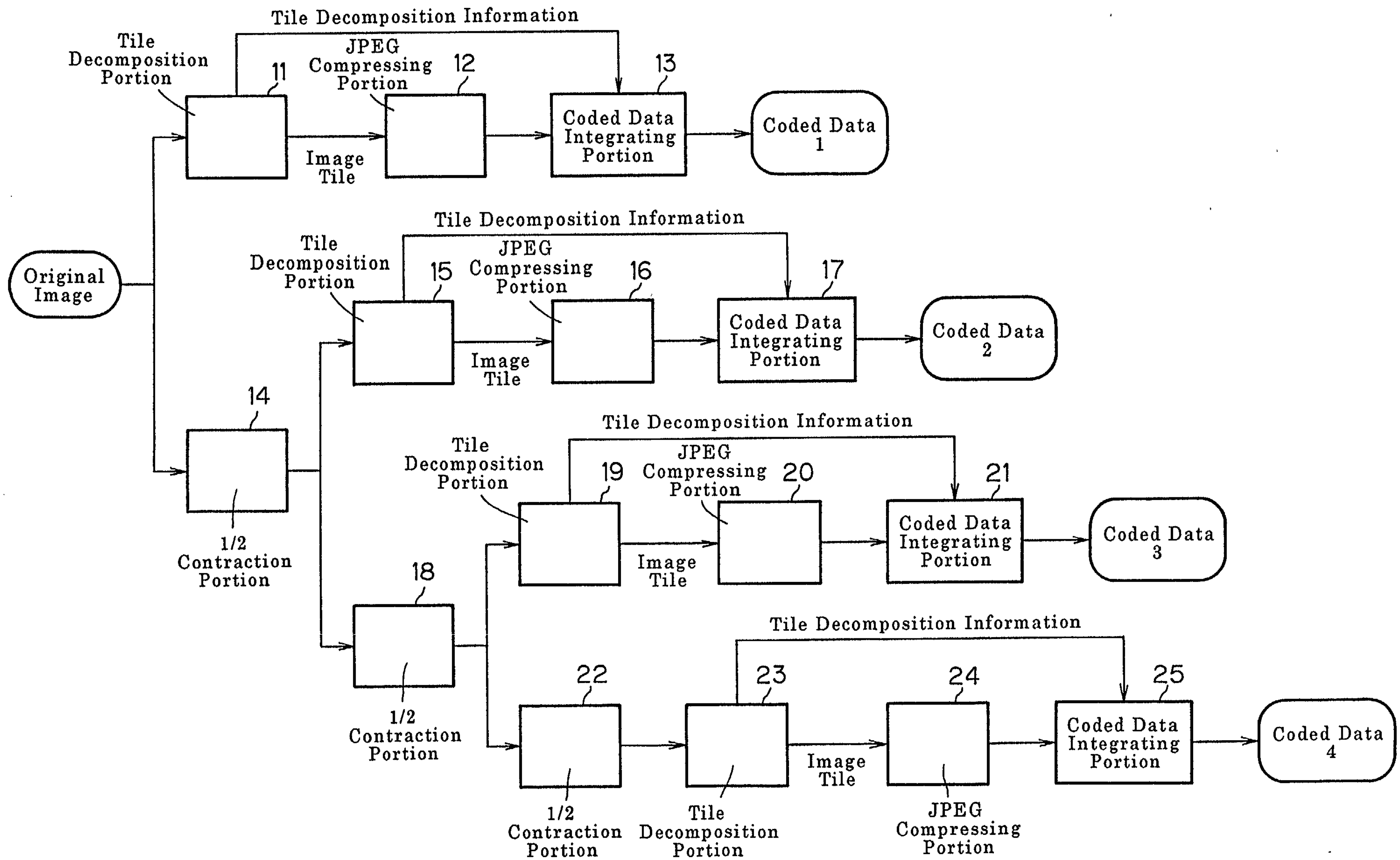


FIG.2



Original Image
Tile Decomposition Information
Tile Decomposition Portion
11
JPEG Compressing Portion
12
13
Coded Data Integrating Portion
Coded Data 1
Image Tile
Tile Decomposition Information
Tile Decomposition Portion
15
JPEG Compressing Portion
16
17
Coded Data Integrating Portion
Coded Data 2
Image Tile
14
1/2 Contraction Portion
Tile Decomposition Information
Tile Decomposition Portion
19
JPEG Compressing Portion
20
21
Coded Data Integrating Portion
Coded Data 3
Image Tile
18
1/2 Contraction Portion
Tile Decomposition Information
22
23
24
25
Coded Data Integrating Portion
Coded Data 4
Image Tile
1/2 Contraction Portion
Tile Decomposition Portion
JPEG Compressing Portion

FIG.3

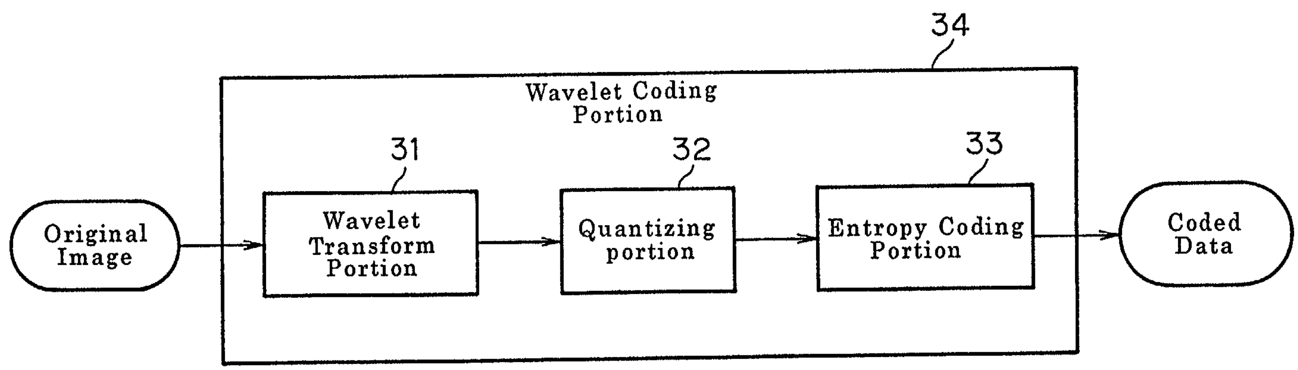

Original Image
Wavelet Coding Portion
34
31
Wavelet Transform Portion
32
Quantizing portion
33
Entropy Coding Portion
Coded Data

FIG.4

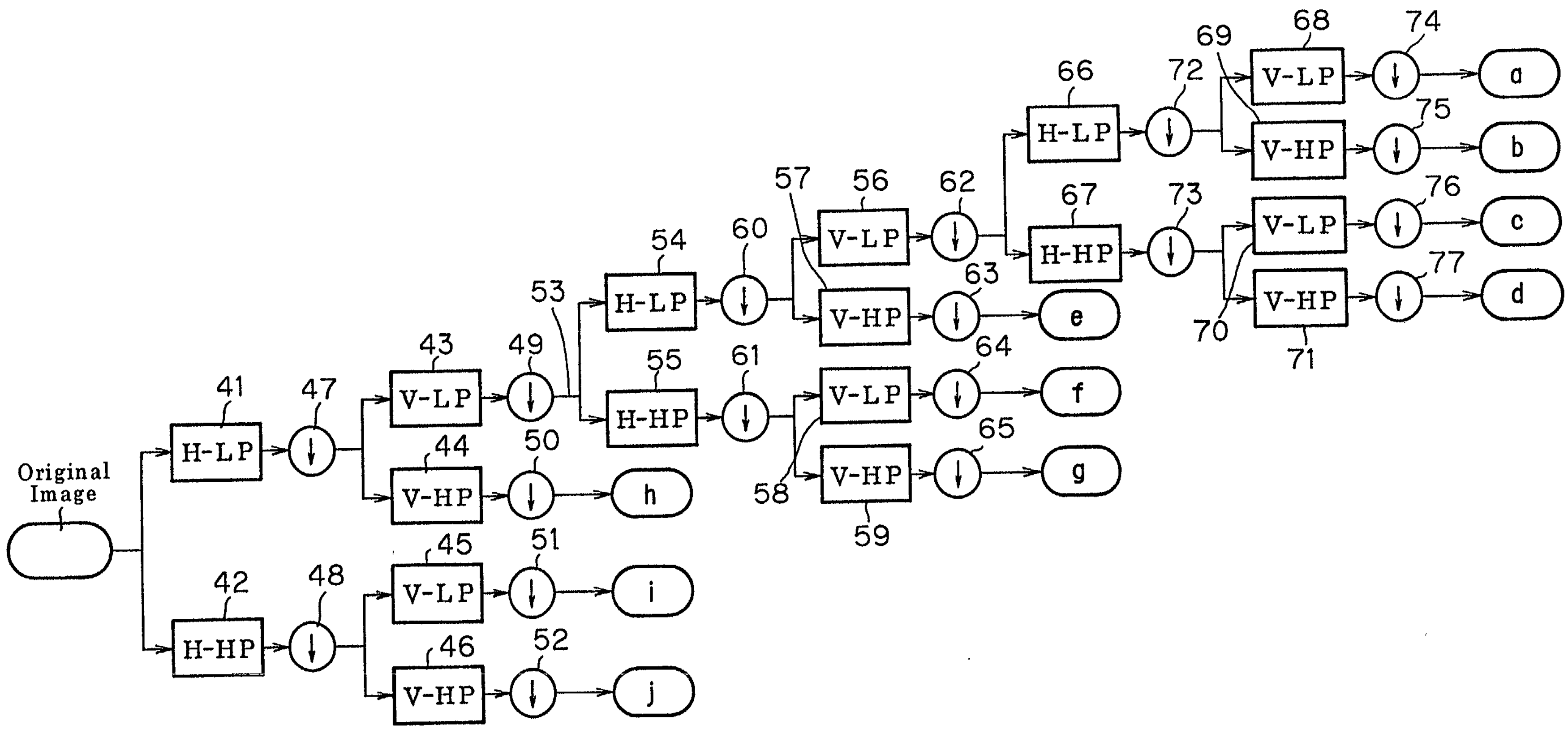

Original Image
H-LP
H-HP
V-LP
V-HP
V-LP
V-HP
h
i
j
H-LP
H-HP
V-LP
V-HP
V-LP
V-HP
e
f
g
H-LP
H-HP
V-LP
V-HP
V-LP
V-HP
a
b
c
d
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77

FIG.5

(A)

Original Image

(B)

Wavelet Transform Data

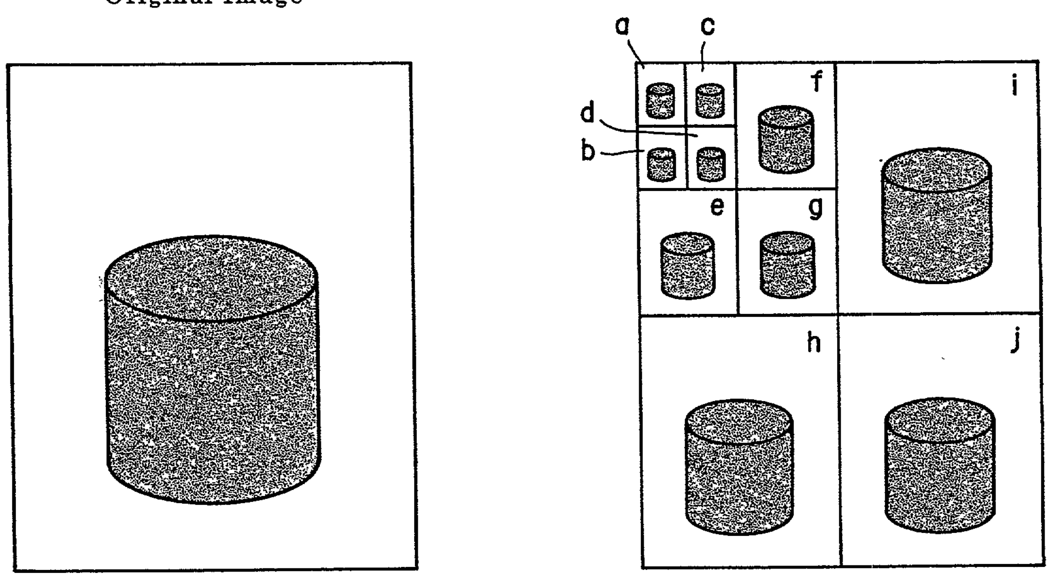


FIG.6

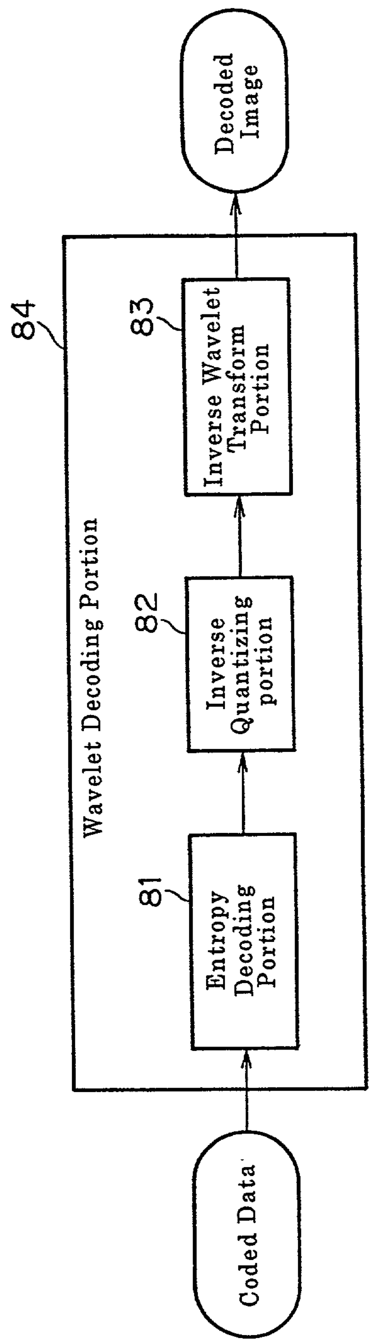
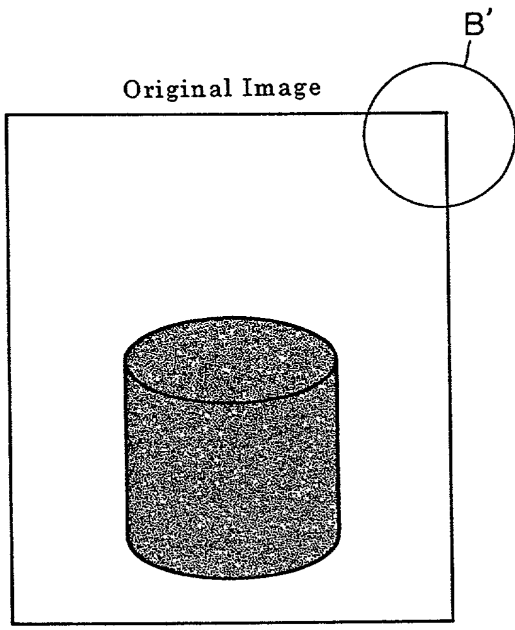

Coded Data
Wavelet Decoding Portion
84
81
Entropy Decoding Portion
82
Inverse Quantizing portion
83
Inverse Wavelet Transform Portion
Decoded Image

FIG.7

(A)


B'
Original Image

(B)

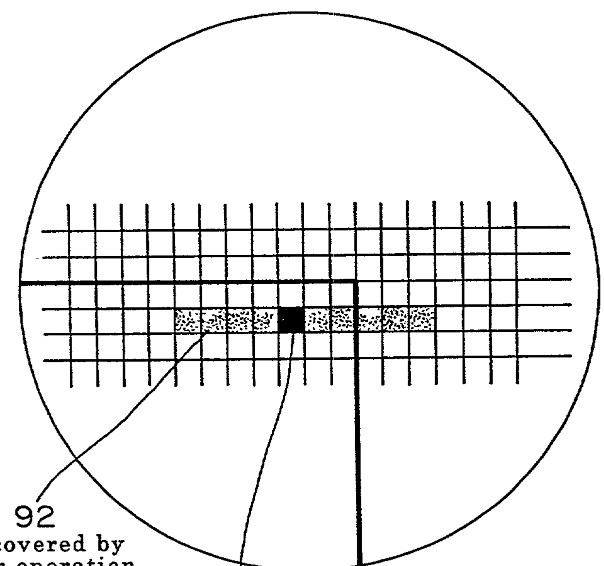
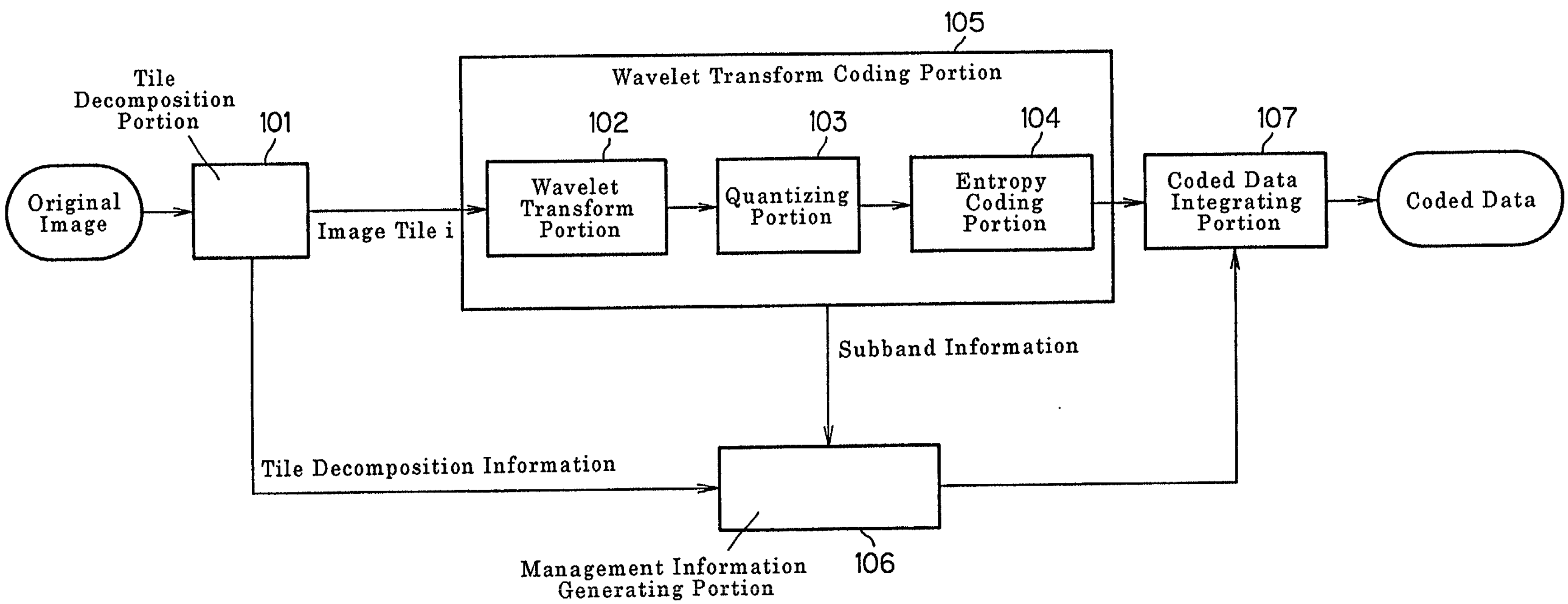

92
Area covered by
a Filter operation
91
Filtered Pixel

FIG.8



Original Image
Tile Decomposition Portion
101
Image Tile i
105
Wavelet Transform Coding Portion
102
Wavelet Transform Portion
103
Quantizing Portion
104
Entropy Coding Portion
107
Coded Data Integrating Portion
Coded Data
Subband Information
Tile Decomposition Information
Management Information Generating Portion
106

FIG.9

(A) Original Image

(B) Tile Decomposition

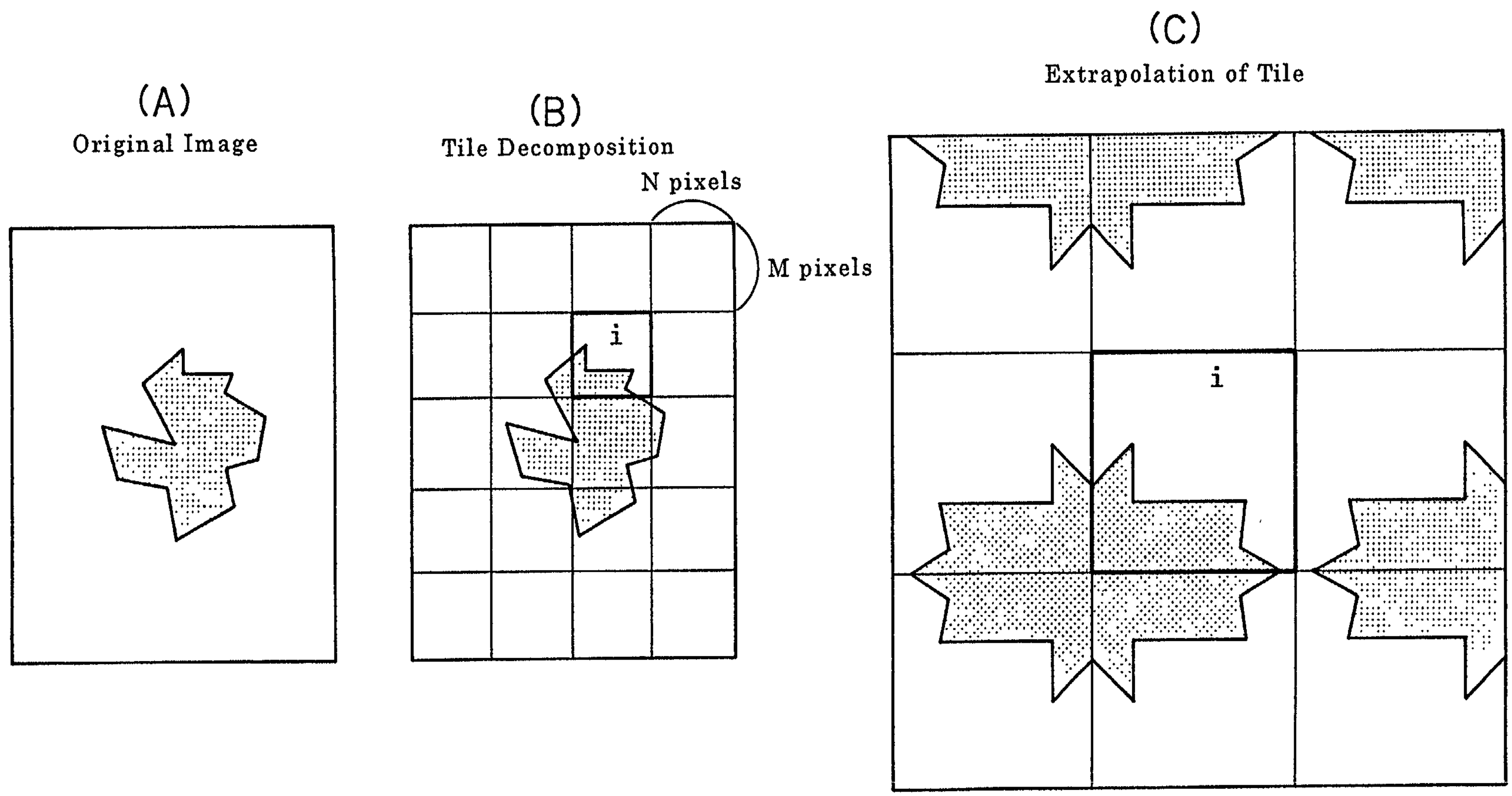
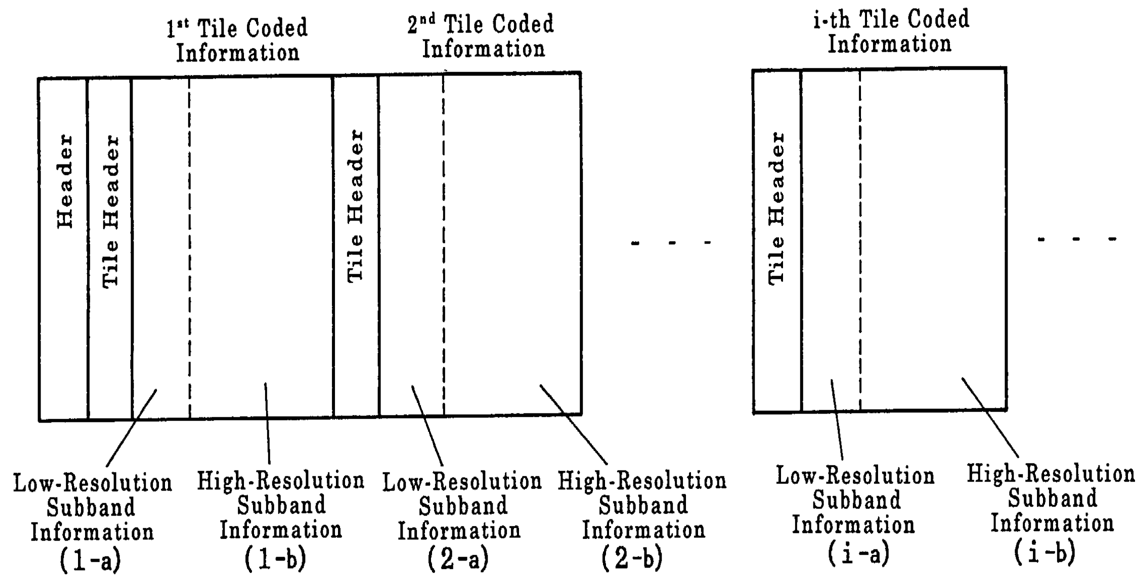


FIG.10



1st Tile Coded Information
2nd Tile Coded Information
i-th Tile Coded Information
Header
Tile Header
Tile Header
Tile Header
Low-Resolution Subband Information (1-a)
High-Resolution Subband Information (1-b)
Low-Resolution Subband Information (2-a)
High-Resolution Subband Information (2-b)
Low-Resolution Subband Information (i-a)
High-Resolution Subband Information (i-b)

FIG.11

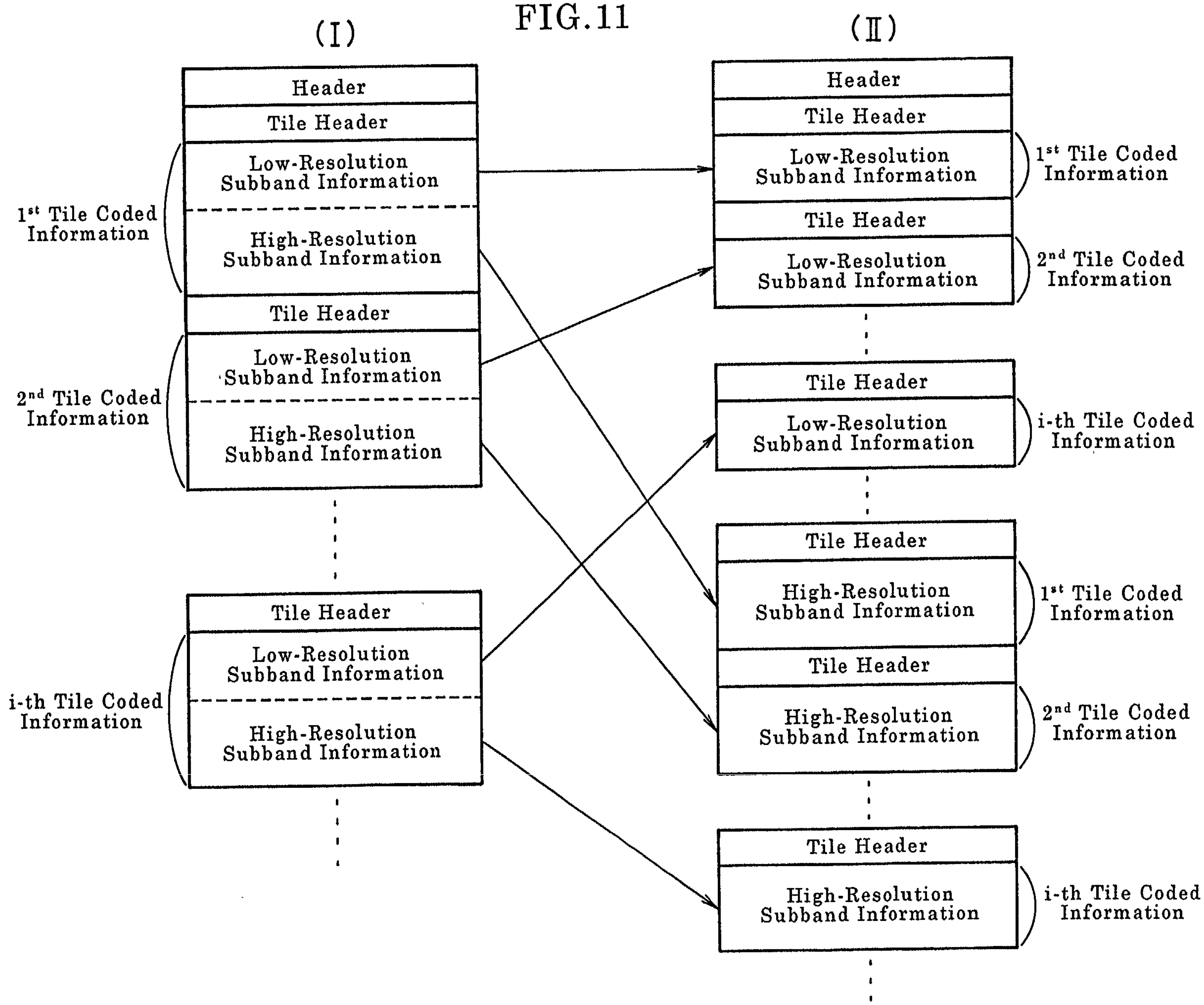

(I)
Header
Tile Header
Low-Resolution Subband Information
High-Resolution Subband Information
Tile Header
Low-Resolution Subband Information
High-Resolution Subband Information
Tile Header
Low-Resolution Subband Information
High-Resolution Subband Information
1st Tile Coded Information
2nd Tile Coded Information
i-th Tile Coded Information
(II)
Header
Tile Header
Low-Resolution Subband Information
Tile Header
Low-Resolution Subband Information
Tile Header
Low-Resolution Subband Information
Tile Header
High-Resolution Subband Information
Tile Header
High-Resolution Subband Information
Tile Header
High-Resolution Subband Information
1st Tile Coded Information
2nd Tile Coded Information
i-th Tile Coded Information
1st Tile Coded Information
2nd Tile Coded Information
i-th Tile Coded Information

FIG.12

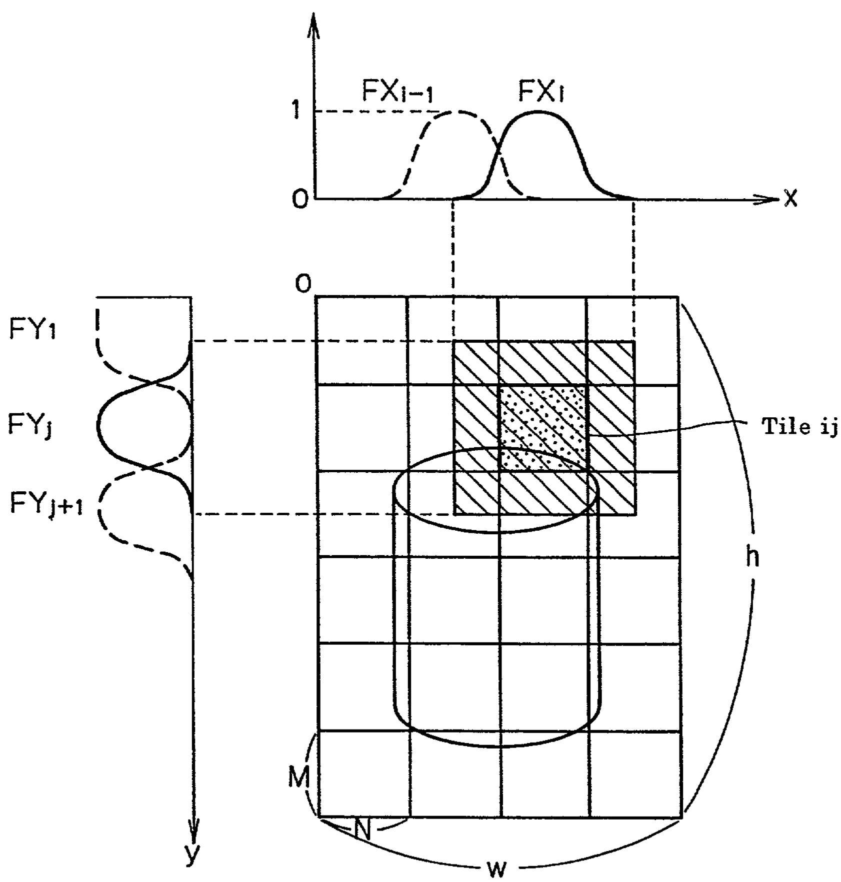


FIG.13

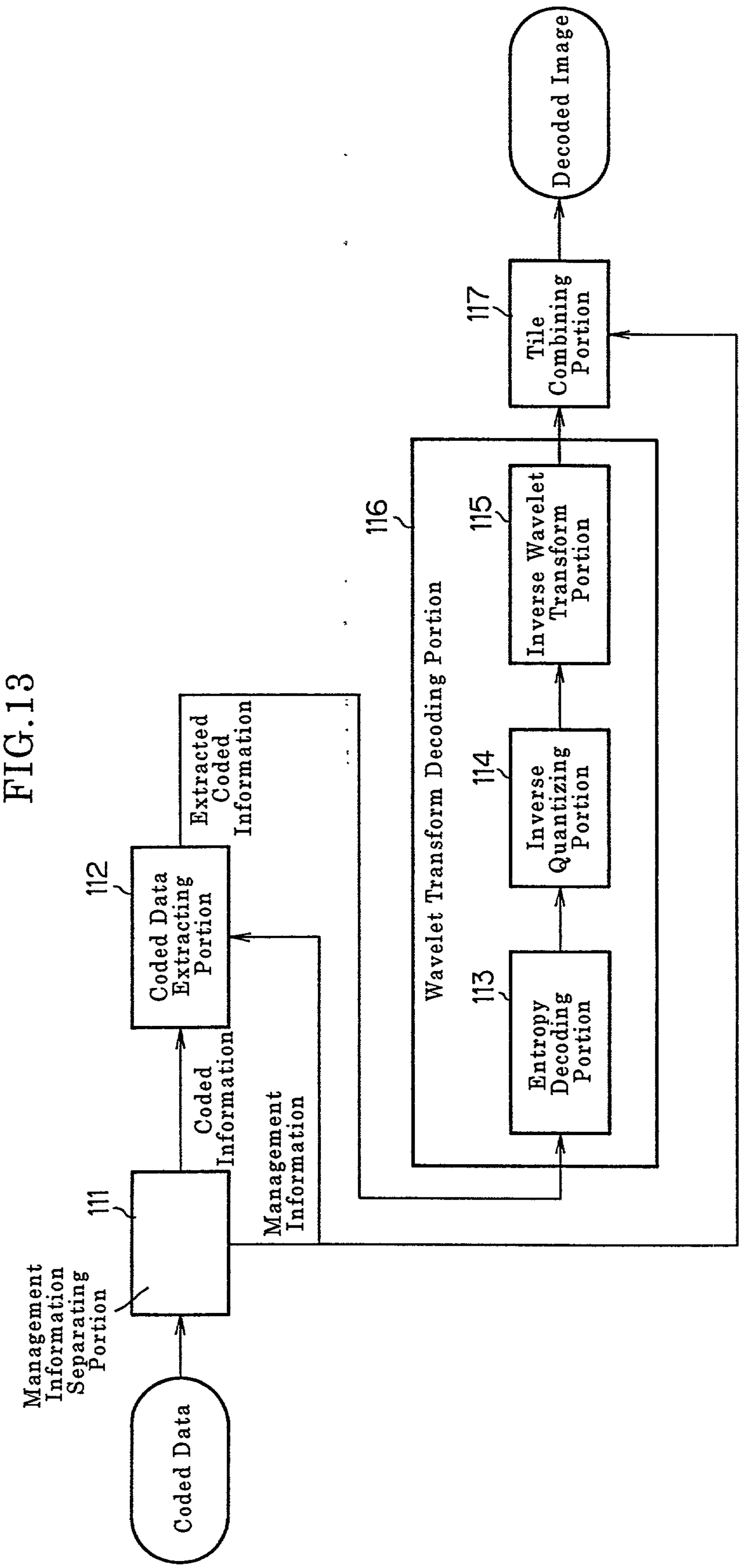

Coded Data
Management Information Separating Portion
111
Coded Information
Management Information
112
Coded Data Extracting Portion
Extracted Coded Information
116
Wavelet Transform Decoding Portion
113
Entropy Decoding Portion
114
Inverse Quantizing Portion
115
Inverse Wavelet Transform Portion
117
Tile Combining Portion
Decoded Image

FIG.14

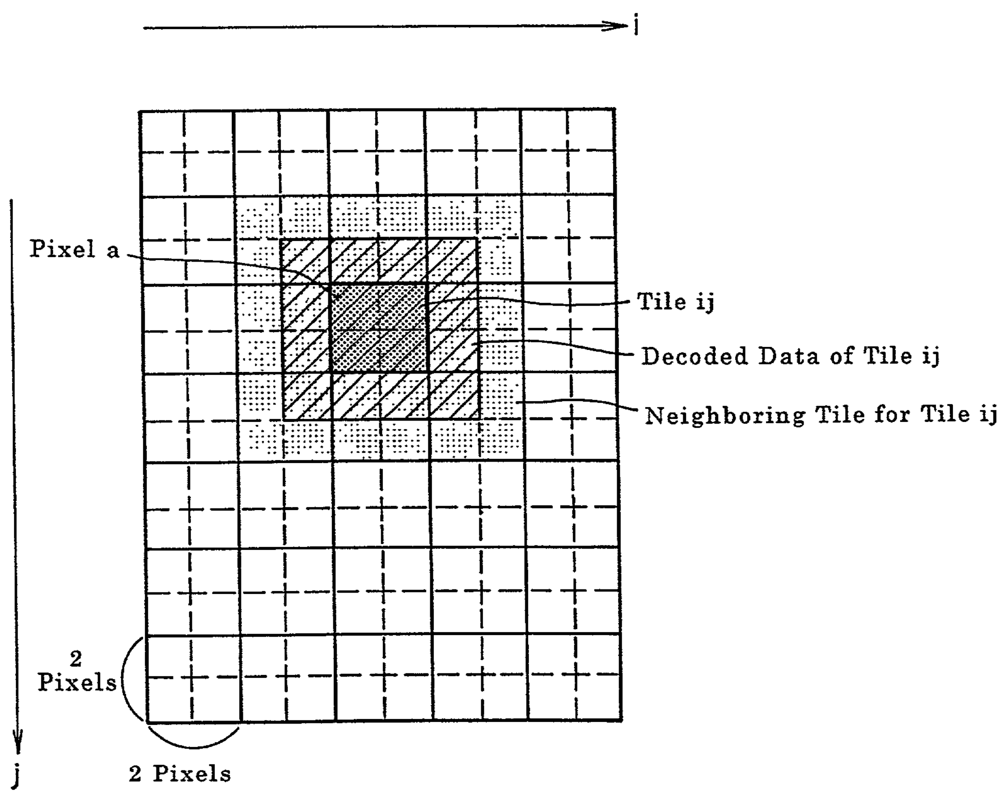

i
Pixel a
Tile ij
Decoded Data of Tile ij
Neighboring Tile for Tile ij
2
Pixels
j
2 Pixels

FIG.15

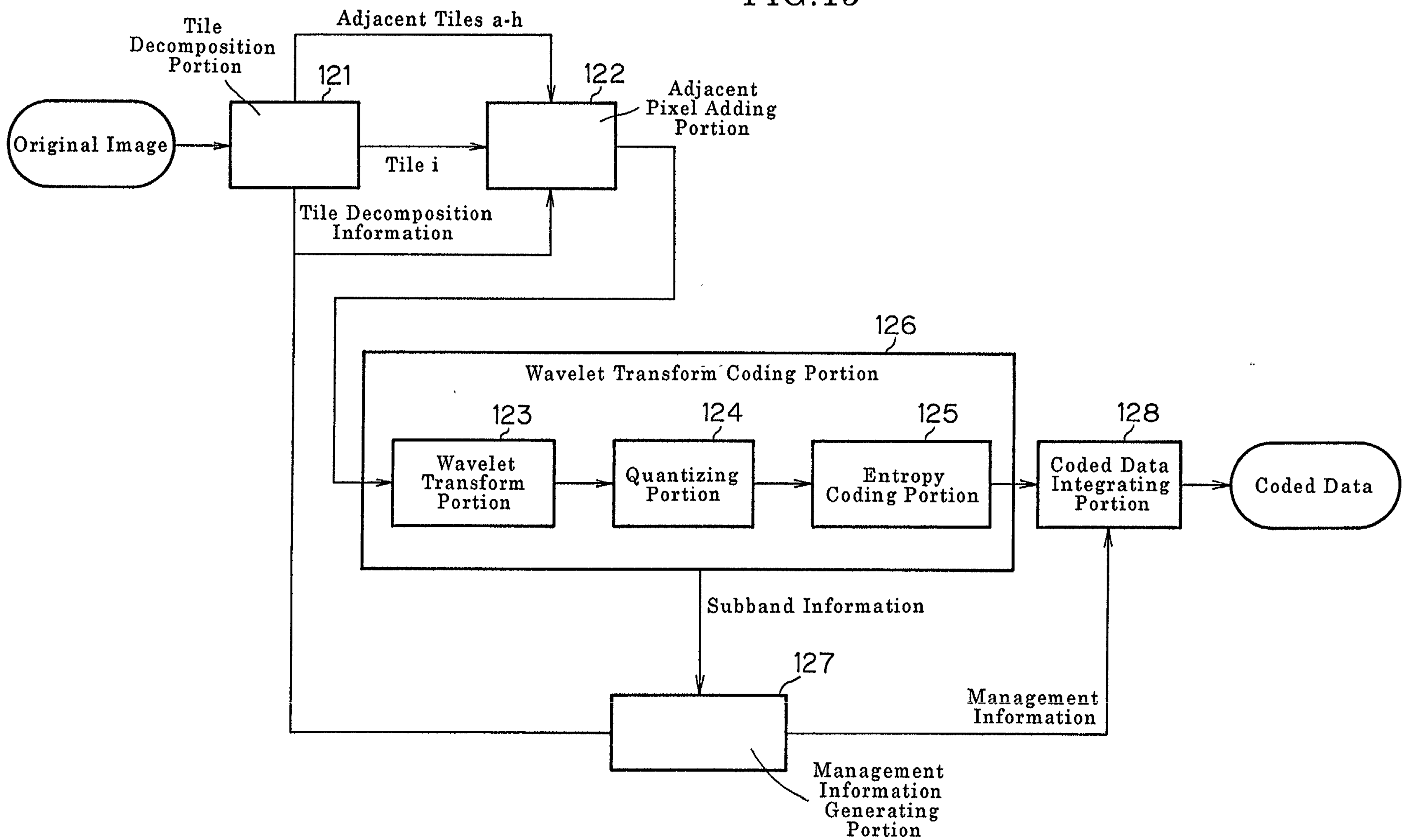

Original Image
Tile Decomposition Portion
121
Adjacent Tiles a-h
Tile i
Tile Decomposition Information
122
Adjacent Pixel Adding Portion
126
Wavelet Transform Coding Portion
123
Wavelet Transform Portion
124
Quantizing Portion
125
Entropy Coding Portion
128
Coded Data Integrating Portion
Coded Data
Subband Information
127
Management Information
Management Information Generating Portion

FIG.16

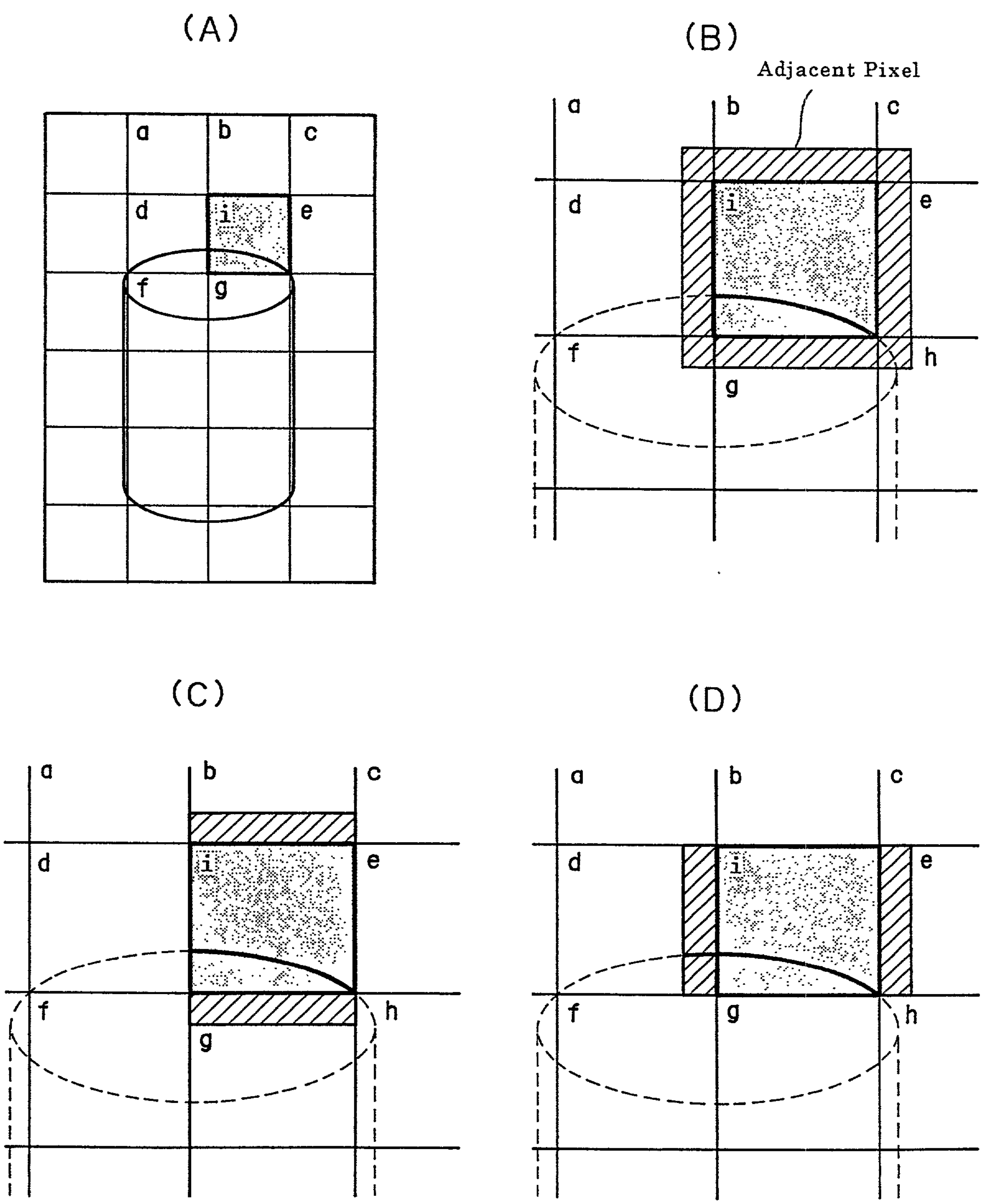

(A)
a
b
c
d
i
e
f
g
(B)
Adjacent Pixel
a
b
c
d
i
e
f
h
g
(C)
a
b
c
d
i
e
f
h
g
(D)
a
b
c
d
i
e
f
g
h

FIG.17

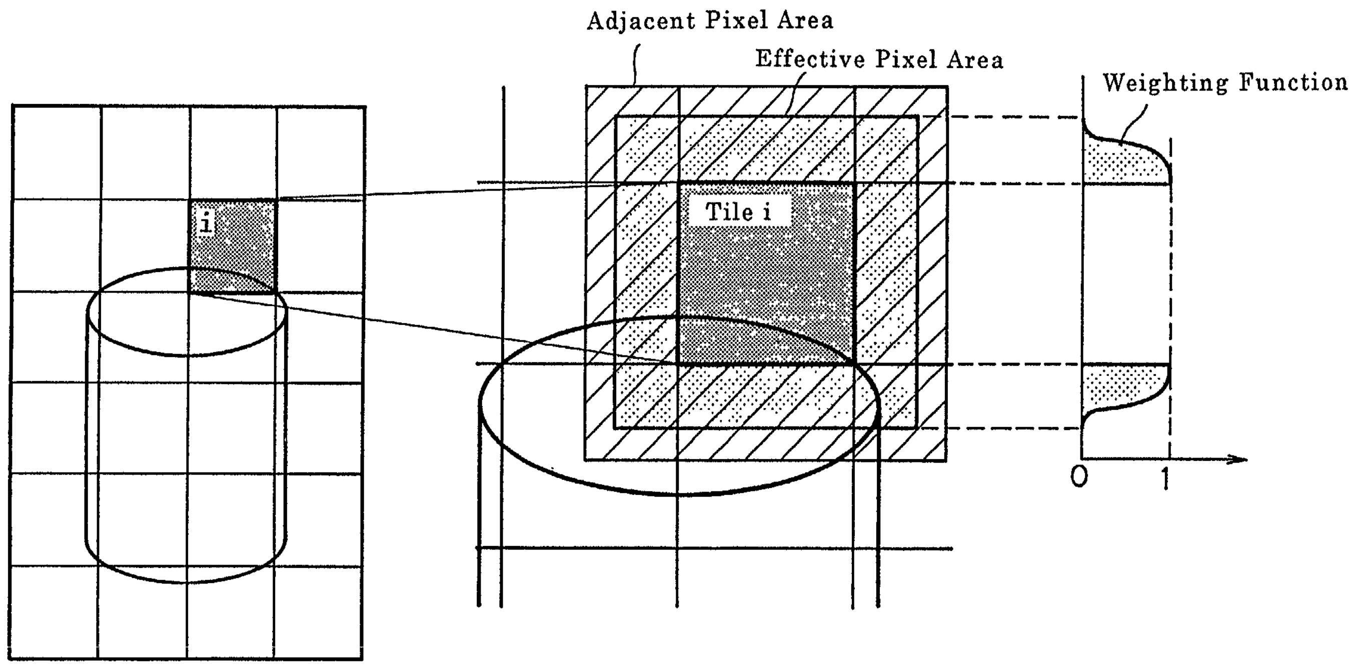
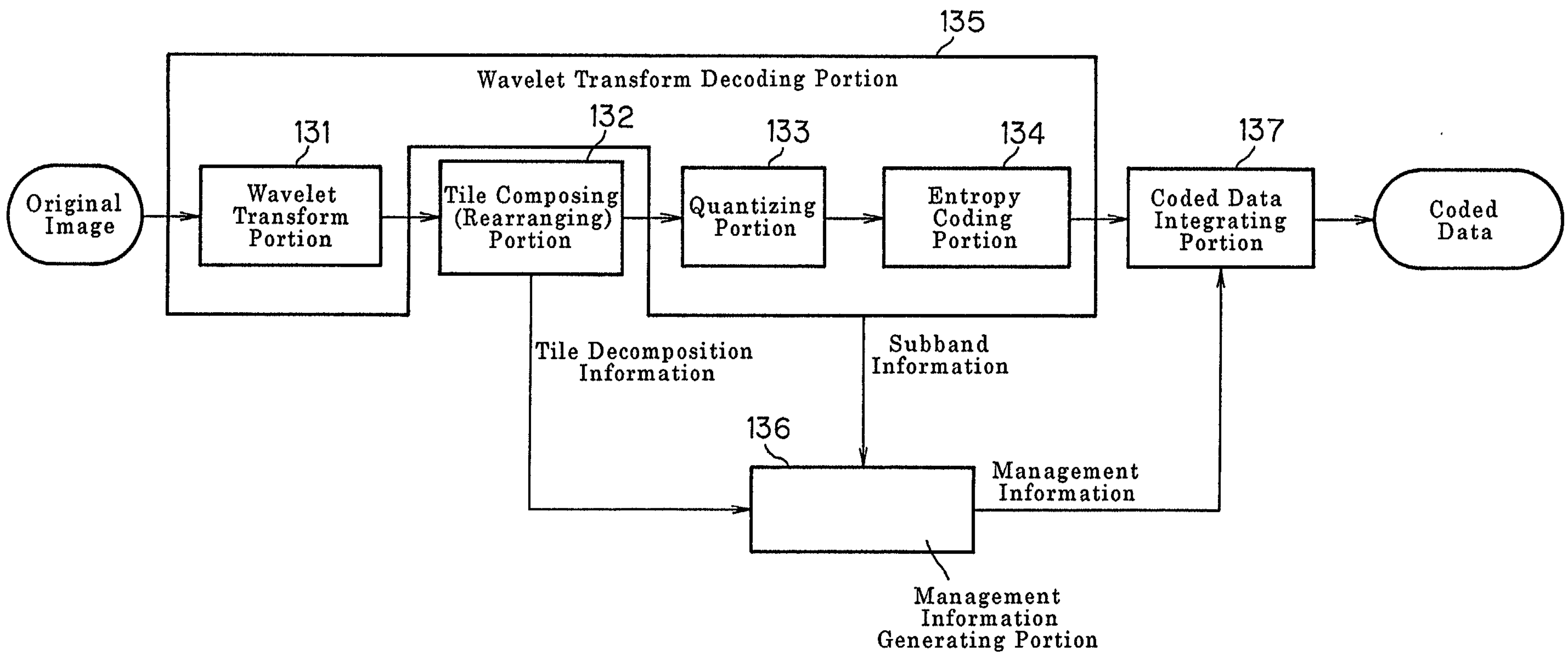

Adjacent Pixel Area
Effective Pixel Area
Weighting Function
Tile i
i
0
1

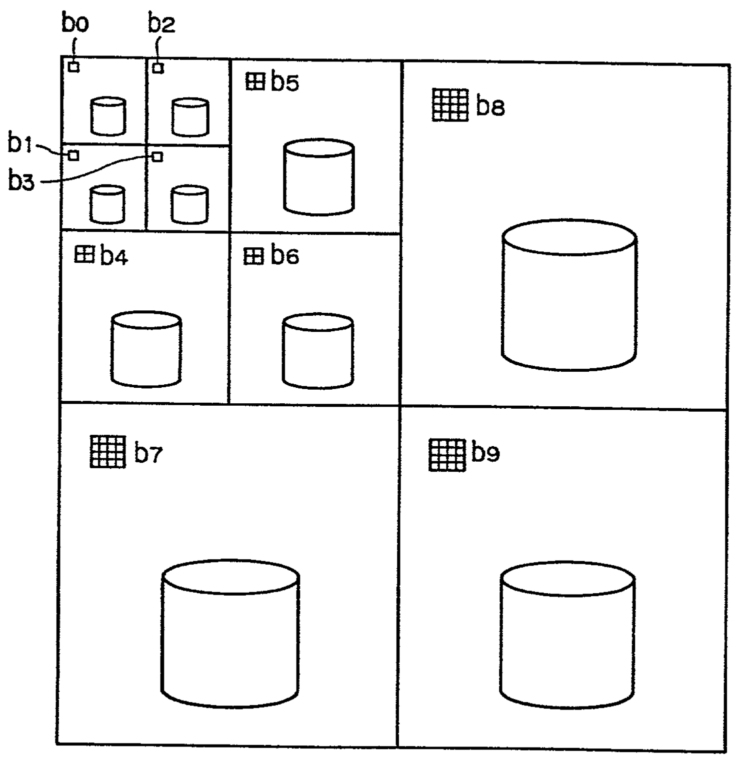
FIG.18



135
Wavelet Transform Decoding Portion
131
Original Image
Wavelet Transform Portion
132
Tile Composing (Rearranging) Portion
133
Quantizing Portion
134
Entropy Coding Portion
137
Coded Data Integrating Portion
Coded Data
Tile Decomposition Information
Subband Information
136
Management Information
Management Information Generating Portion

FIG.19

(A)



(B)

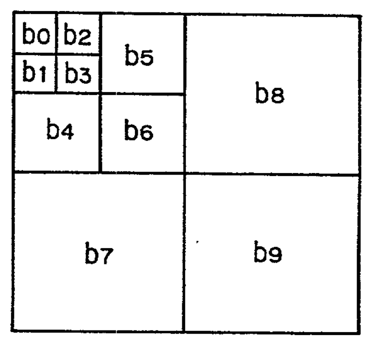


FIG.20

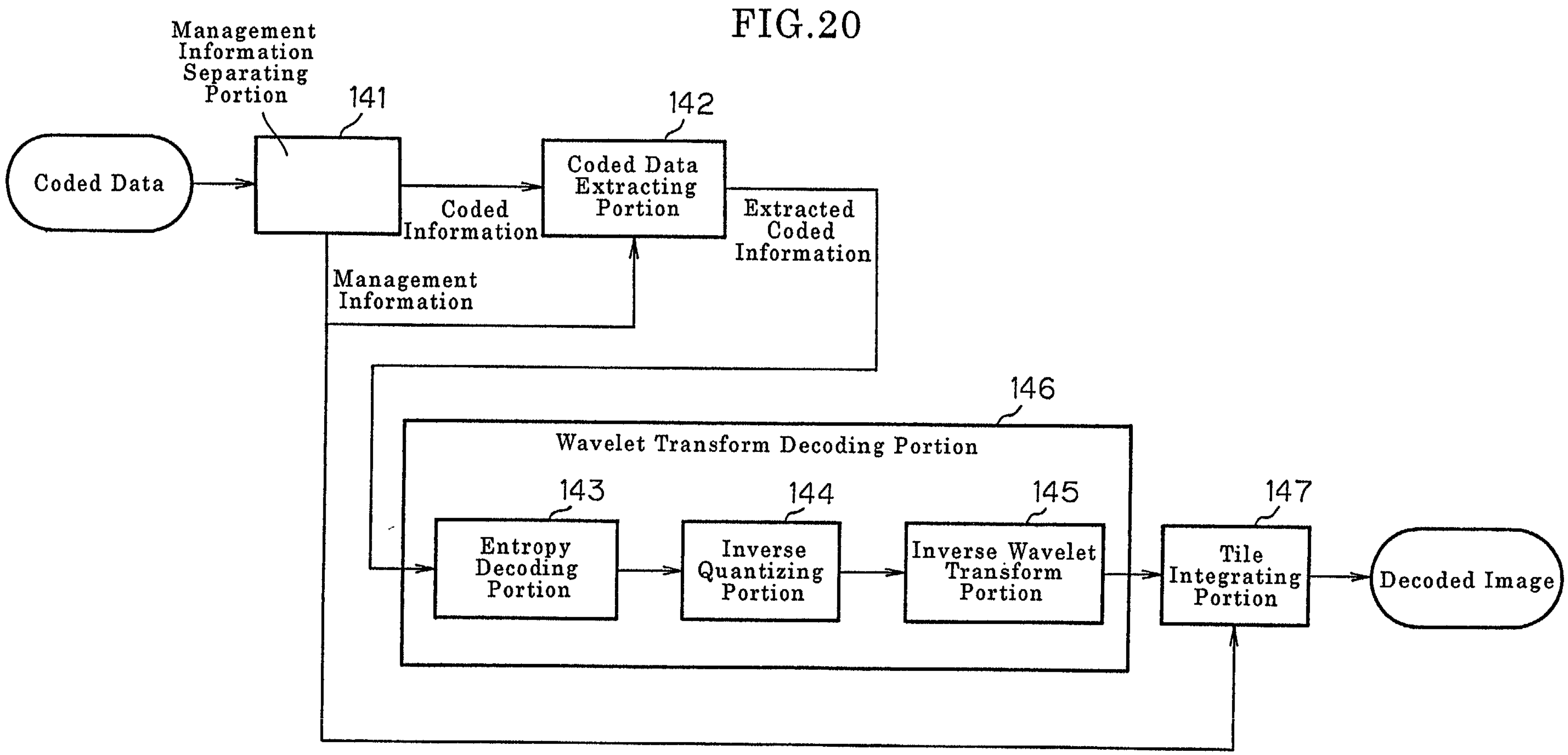
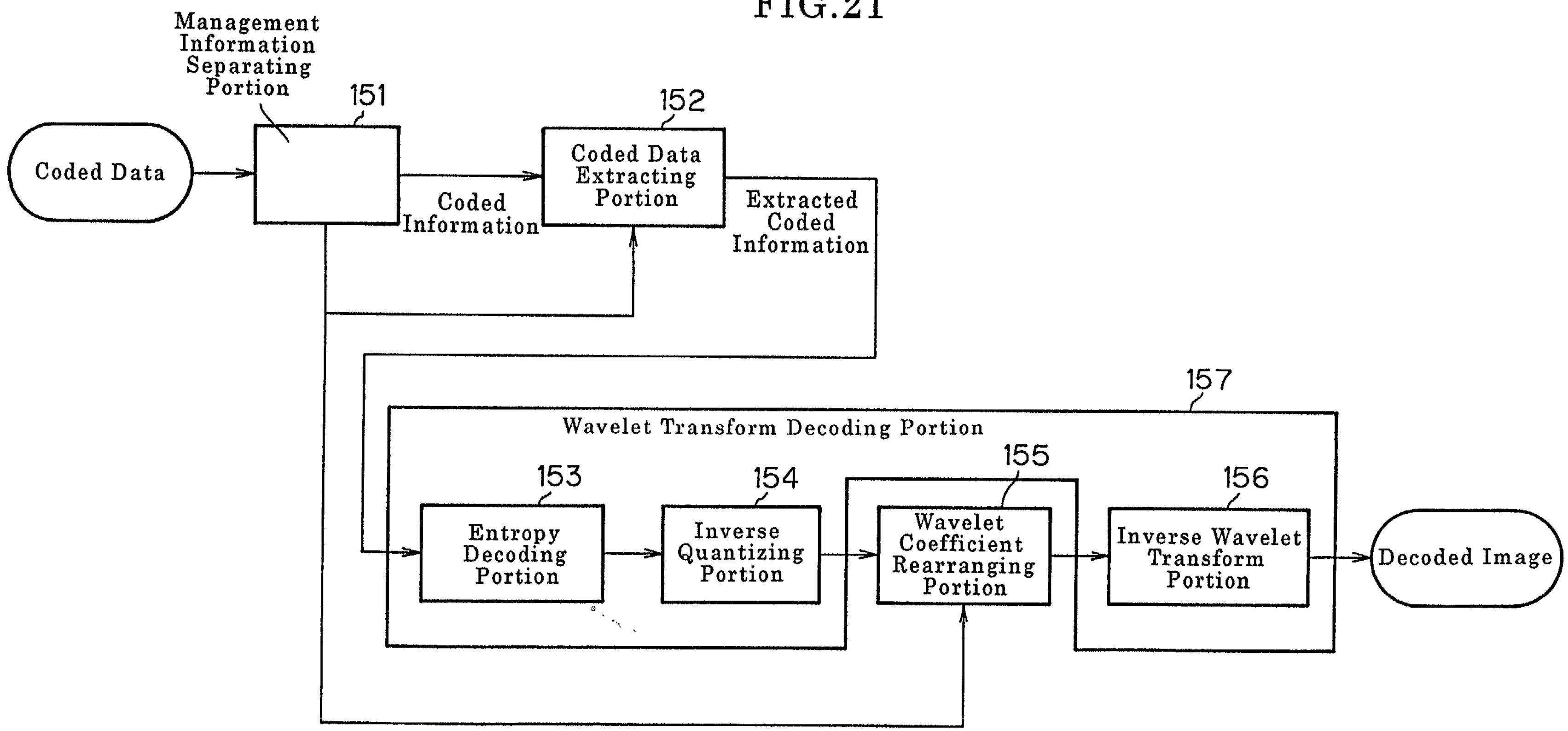

Management
Information
Separating
Portion
141
Coded Data
Coded
Information
142
Coded Data
Extracting
Portion
Extracted
Coded
Information
Management
Information
146
Wavelet Transform Decoding Portion
143
Entropy
Decoding
Portion
144
Inverse
Quantizing
Portion
145
Inverse Wavelet
Transform
Portion
147
Tile
Integrating
Portion
Decoded Image

FIG.21



Coded Data
Management Information Separating Portion
151
Coded Information
152
Coded Data Extracting Portion
Extracted Coded Information
157
Wavelet Transform Decoding Portion
153
Entropy Decoding Portion
154
Inverse Quantizing Portion
155
Wavelet Coefficient Rearranging Portion
156
Inverse Wavelet Transform Portion
Decoded Image

FIG.22

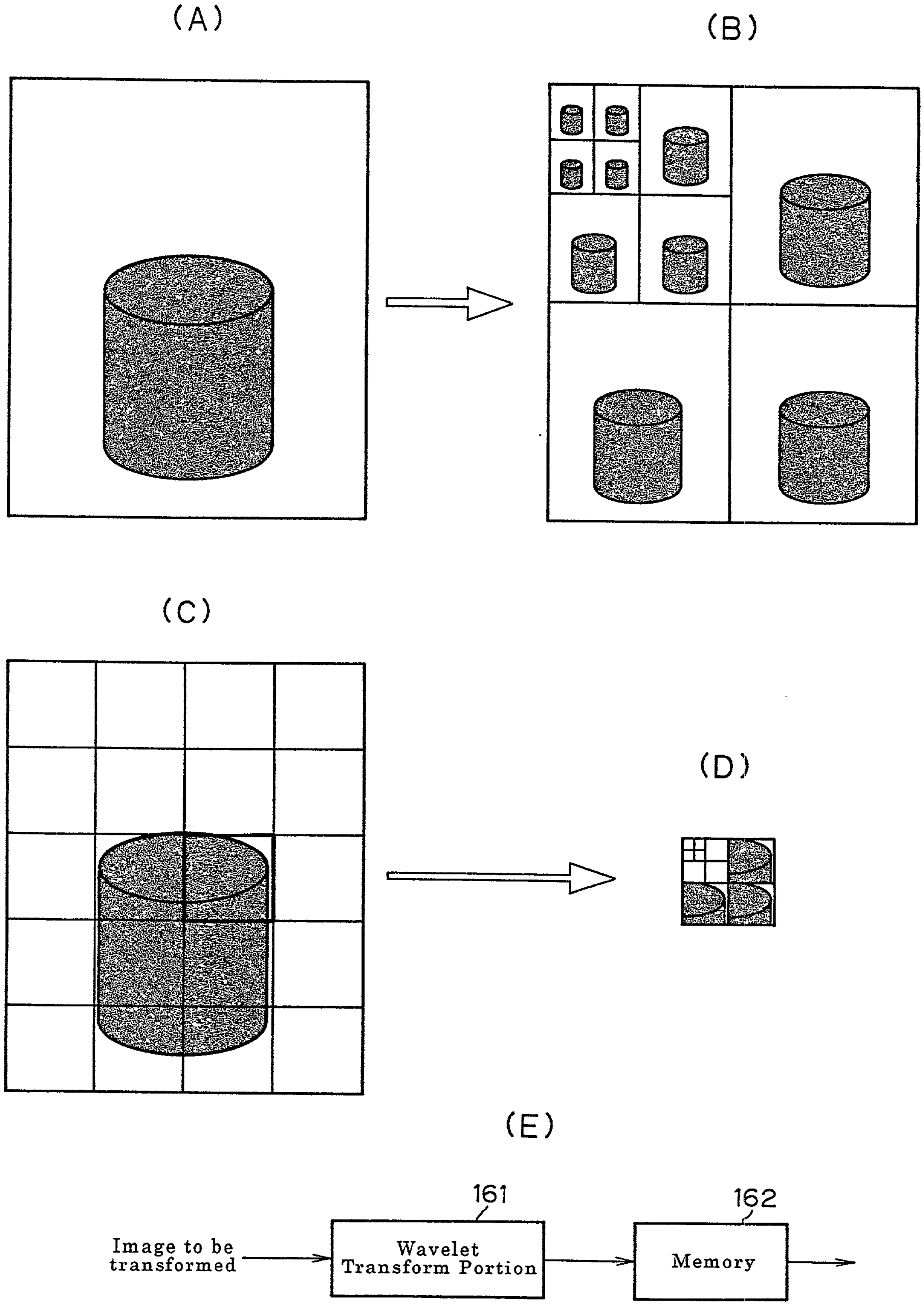

(A)
(B)
(C)
(D)
(E)
161
162
Image to be transformed
Wavelet Transform Portion
Memory

FIG.23

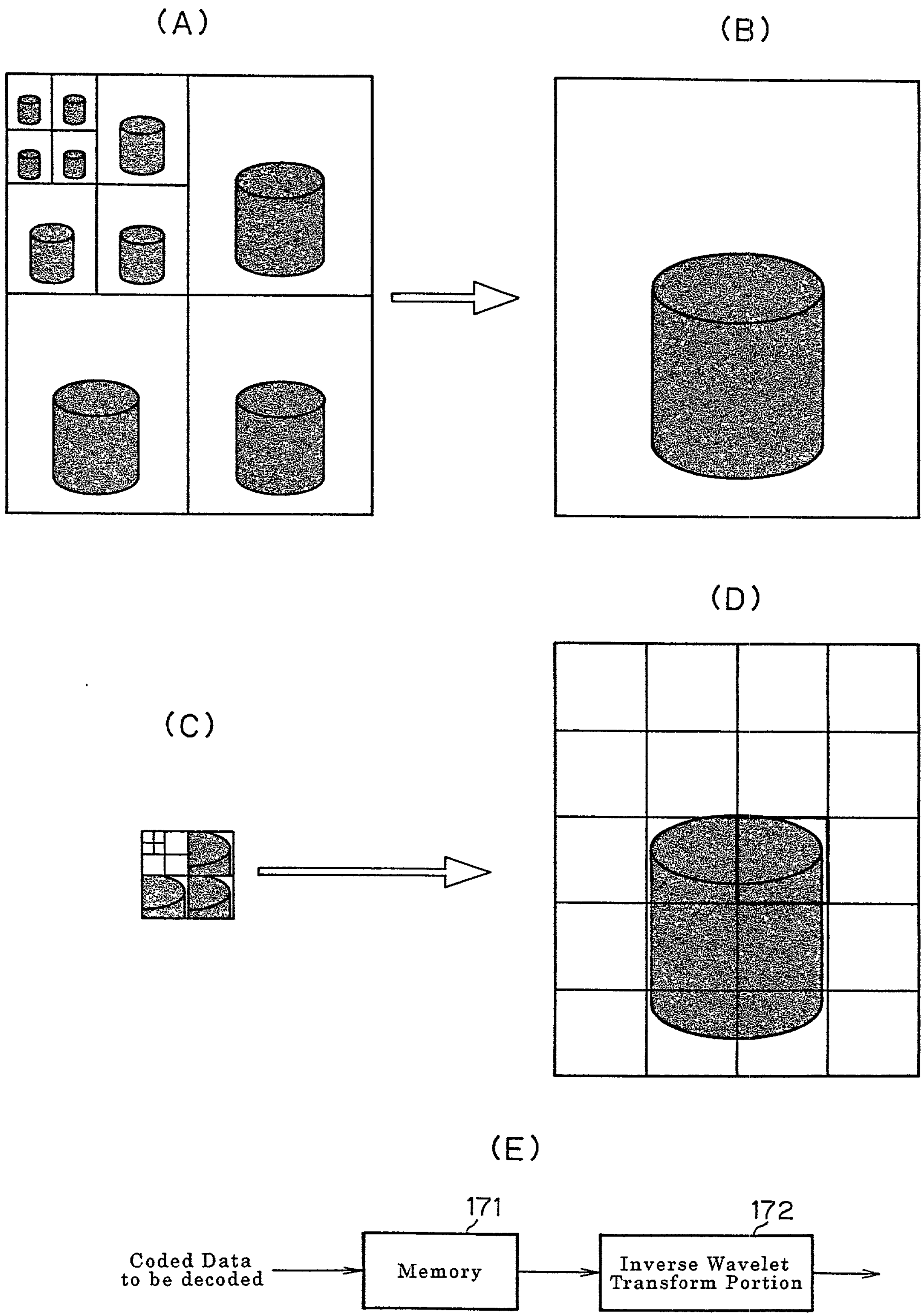
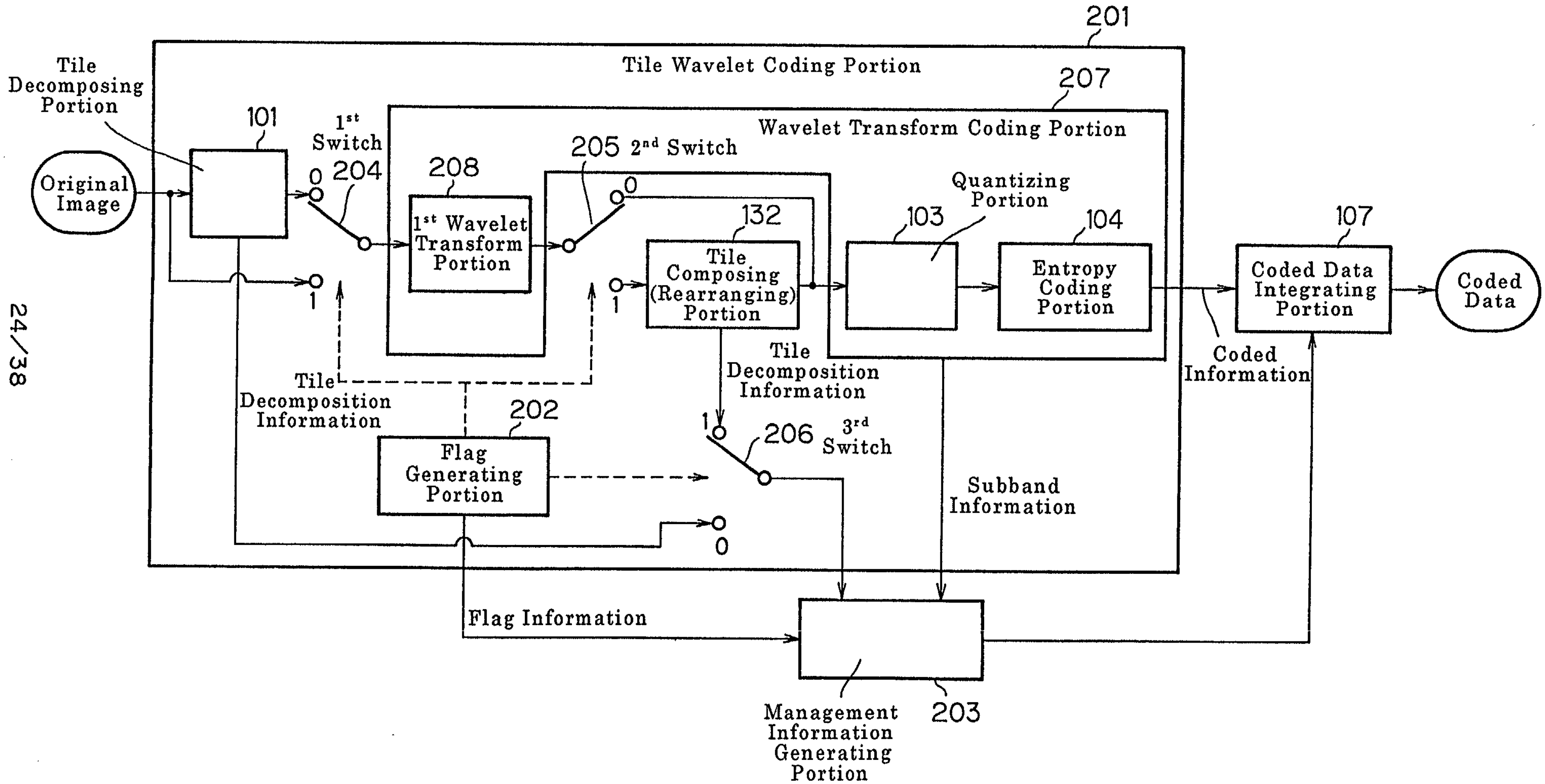

(A)
(B)
(C)
(D)
(E)
171
172
Coded Data
to be decoded
Memory
Inverse Wavelet
Transform Portion

FIG.24



Tile Wavelet Coding Portion
201
Wavelet Transform Coding Portion
207
Tile Decomposing Portion
Original Image
101
1st Switch
204
0
1
208
1st Wavelet Transform Portion
205 2nd Switch
0
1
132
Tile Composing (Rearranging) Portion
103
Quantizing Portion
104
Entropy Coding Portion
107
Coded Data Integrating Portion
Coded Data
Coded Information
Tile Decomposition Information
Tile Decomposition Information
202
Flag Generating Portion
206
3rd Switch
1
0
Subband Information
Flag Information
Management Information Generating Portion
203

FIG.25

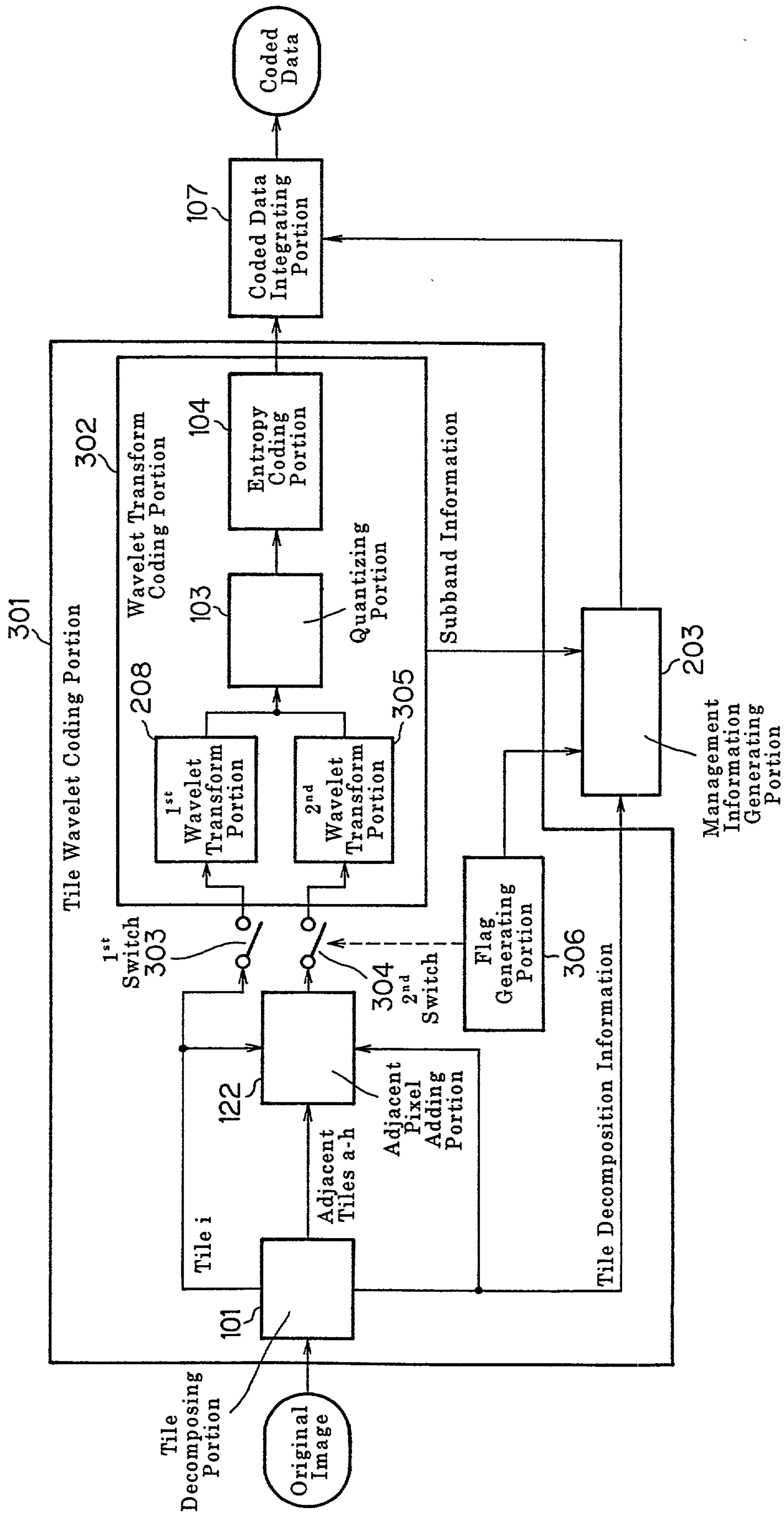

Original Image
Tile Decomposing Portion
101
Tile i
Adjacent Tiles a-h
122
Adjacent Pixel Adding Portion
1st Switch
303
304
2nd Switch
Flag Generating Portion
306
Tile Decomposition Information
301
Tile Wavelet Coding Portion
302
Wavelet Transform Coding Portion
208
1st Wavelet Transform Portion
305
2nd Wavelet Transform Portion
103
Quantizing Portion
104
Entropy Coding Portion
Subband Information
203
Management Information Generating Portion
107
Coded Data Integrating Portion
Coded Data

FIG.26

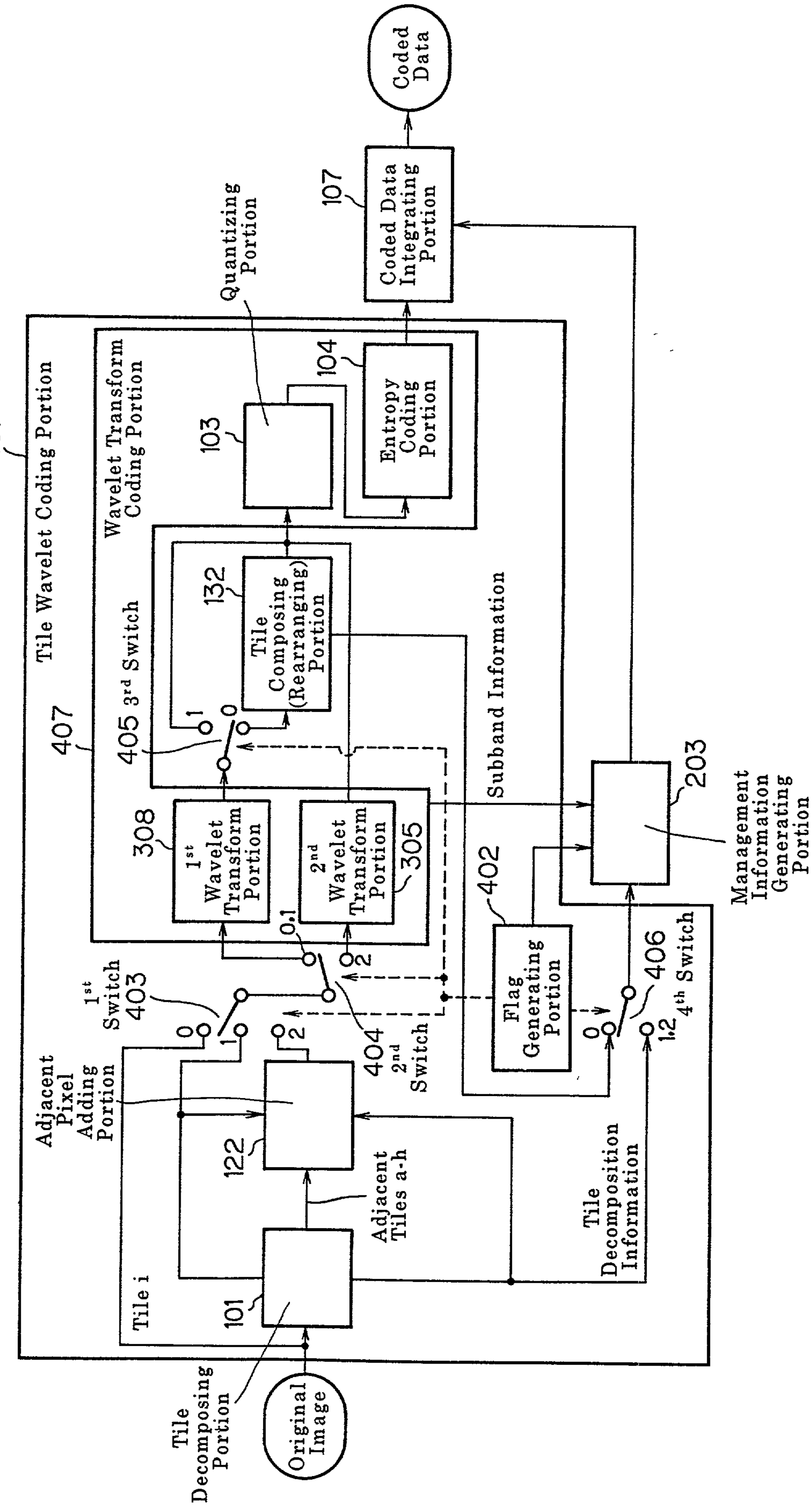

Original Image
Tile Decomposing Portion
101
Tile i
Adjacent Tiles a-h
122
Adjacent Pixel Adding Portion
Tile Decomposition Information
1st Switch
403
0
1
2
404
2nd Switch
0,1
2
401
Tile Wavelet Coding Portion
407
Wavelet Transform Coding Portion
308
1st Wavelet Transform Portion
2nd Wavelet Transform Portion
305
405 3rd Switch
1
0
132
Tile Composing (Rearranging) Portion
103
Quantizing Portion
104
Entropy Coding Portion
Subband Information
402
Flag Generating Portion
406
4th Switch
1,2
203
Management Information Generating Portion
107
Coded Data Integrating Portion
Coded Data

FIG.27

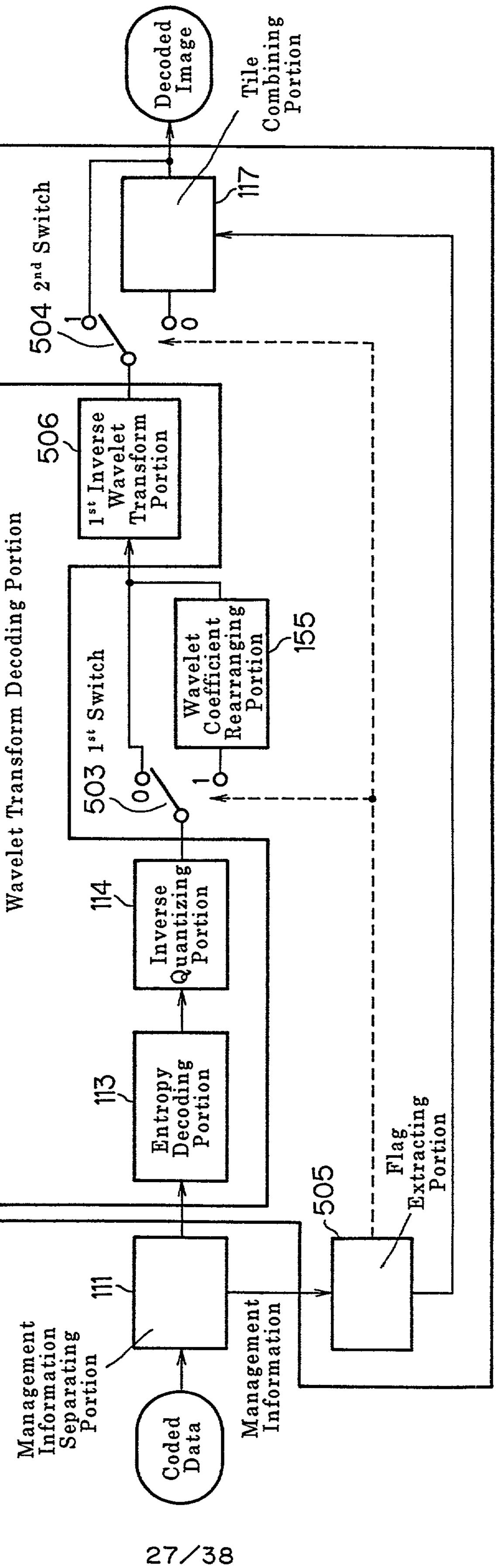

Decoded Image
Tile Combining Portion
117
501
Tile Wavelet Decoding Portion
504 2nd Switch
1
0
506
1st Inverse Wavelet Transform Portion
502
Wavelet Transform Decoding Portion
Wavelet Coefficient Rearranging Portion
155
503 1st Switch
0
1
114
Inverse Quantizing Portion
113
Entropy Decoding Portion
505
Flag Extracting Portion
111
Management Information Separating Portion
Coded Data
Management Information

FIG.28

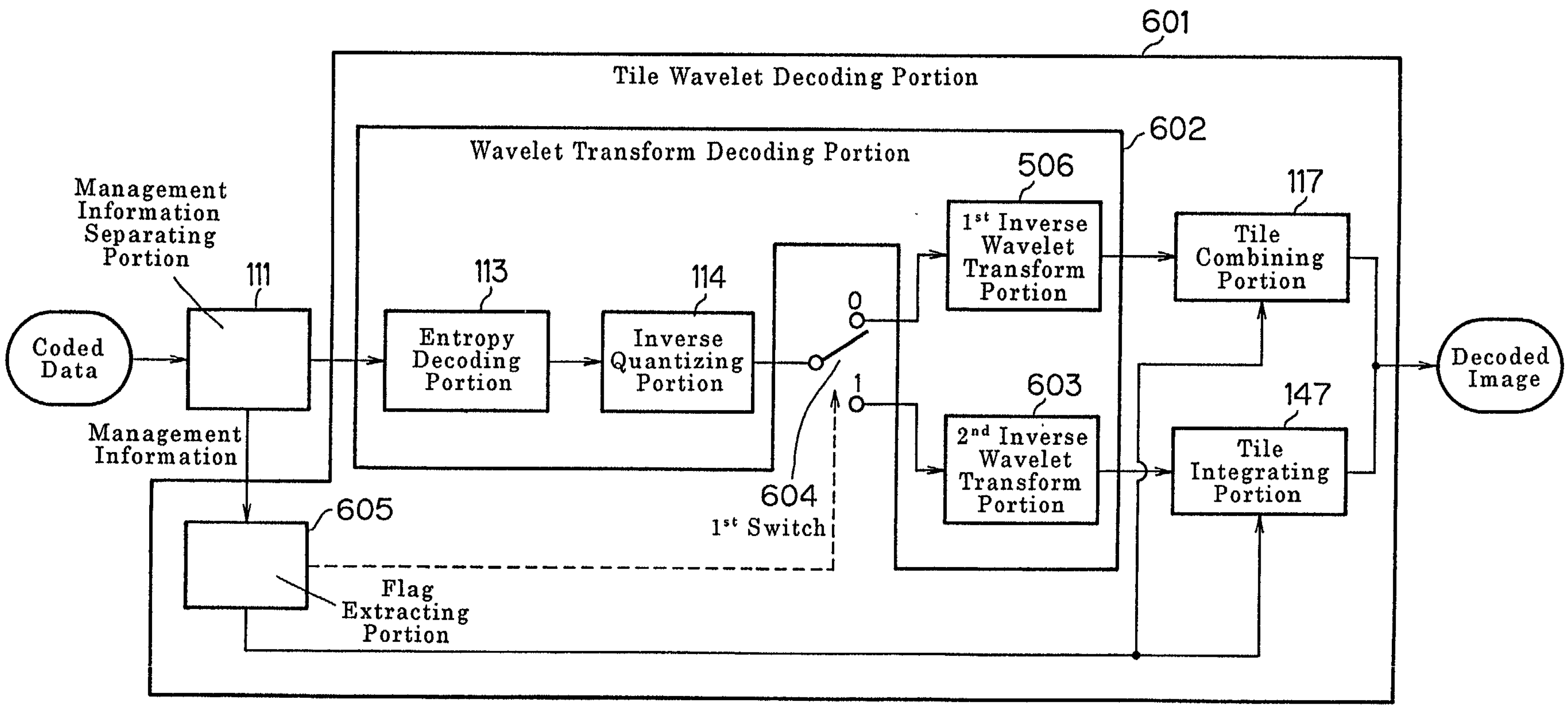

Coded Data
Management Information Separating Portion
111
Management Information
Tile Wavelet Decoding Portion
601
Wavelet Transform Decoding Portion
602
113
Entropy Decoding Portion
114
Inverse Quantizing Portion
0
1
604
1st Switch
506
1st Inverse Wavelet Transform Portion
603
2nd Inverse Wavelet Transform Portion
117
Tile Combining Portion
147
Tile Integrating Portion
605
Flag Extracting Portion
Decoded Image

FIG.29

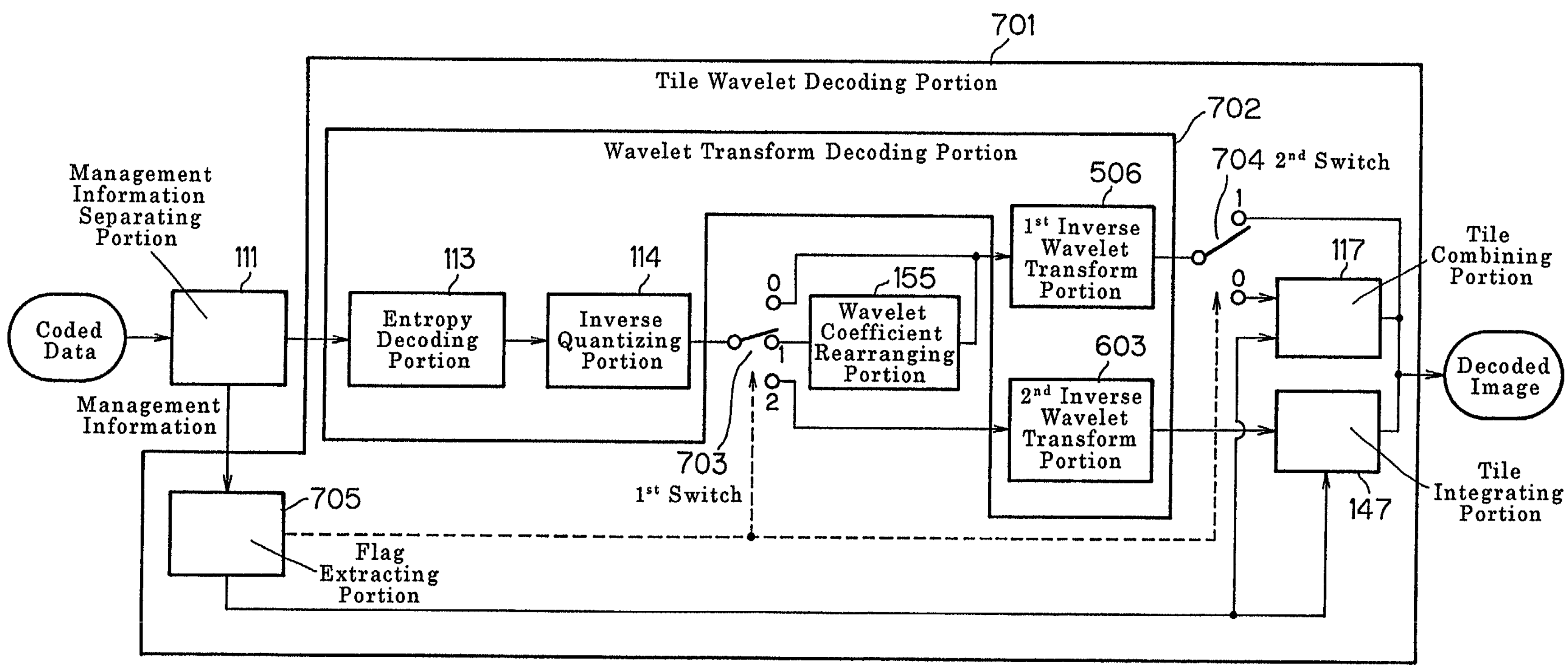
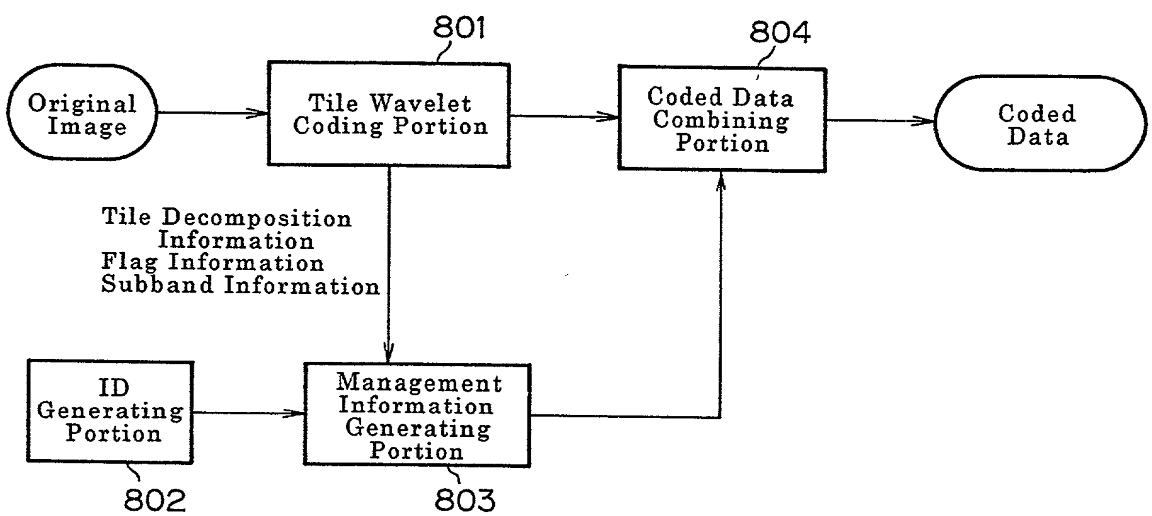

701
Tile Wavelet Decoding Portion
702
Wavelet Transform Decoding Portion
Management Information Separating Portion
111
Coded Data
Management Information
113
Entropy Decoding Portion
114
Inverse Quantizing Portion
155
Wavelet Coefficient Rearranging Portion
0
1
2
703
1st Switch
506
1st Inverse Wavelet Transform Portion
603
2nd Inverse Wavelet Transform Portion
704 2nd Switch
1
0
117
Tile Combining Portion
147
Tile Integrating Portion
Decoded Image
705
Flag Extracting Portion

FIG.30


801
804
Original Image
Tile Wavelet Coding Portion
Coded Data Combining Portion
Coded Data
Tile Decomposition Information
Flag Information
Subband Information
ID Generating Portion
Management Information Generating Portion
802
803

09/508813

FIG.31

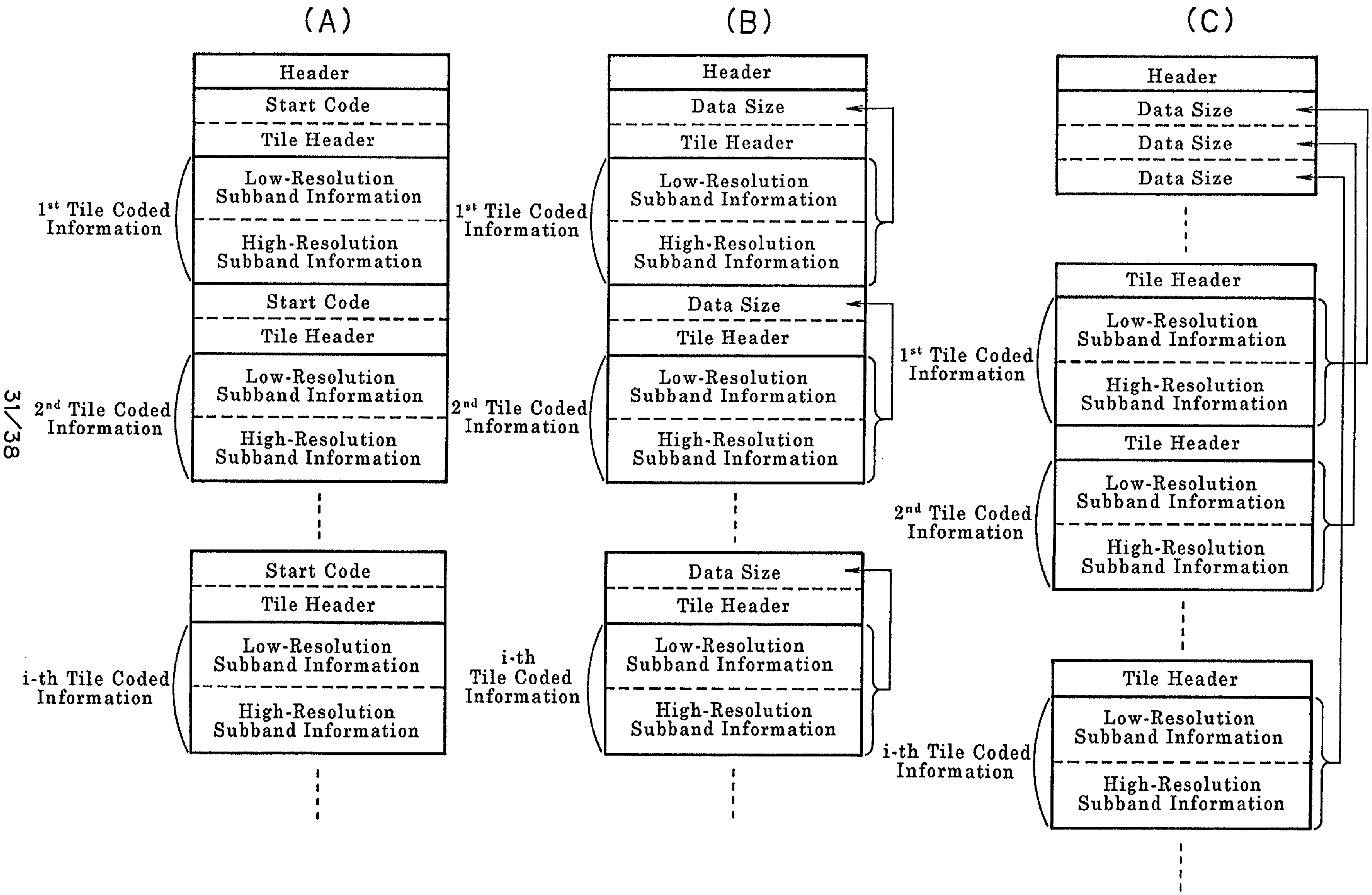


FIG.32

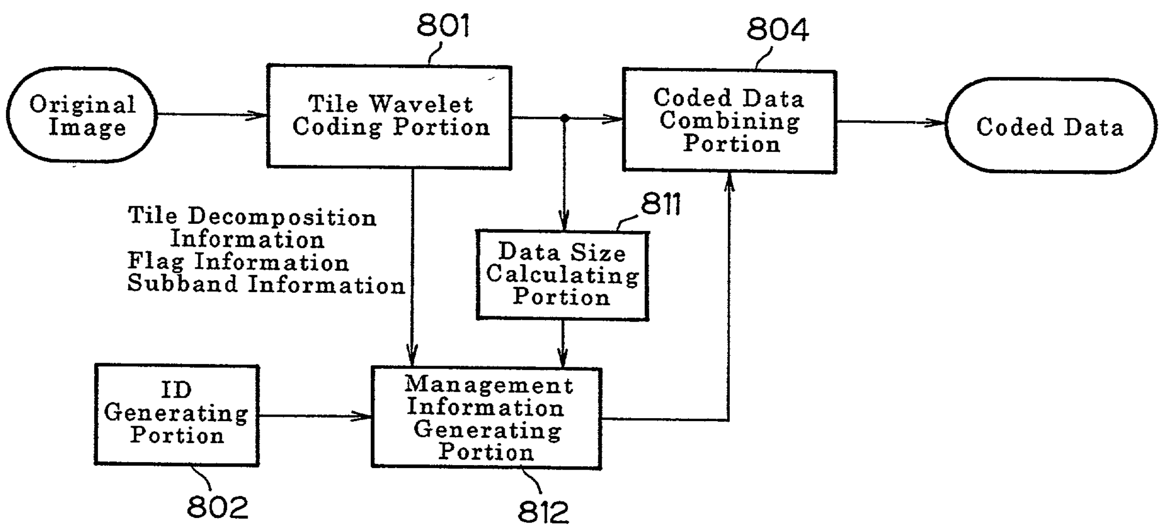

801
804
Original Image
Tile Wavelet Coding Portion
Coded Data Combining Portion
Coded Data
811
Tile Decomposition Information
Flag Information
Subband Information
Data Size Calculating Portion
ID Generating Portion
Management Information Generating Portion
802
812

FIG.33

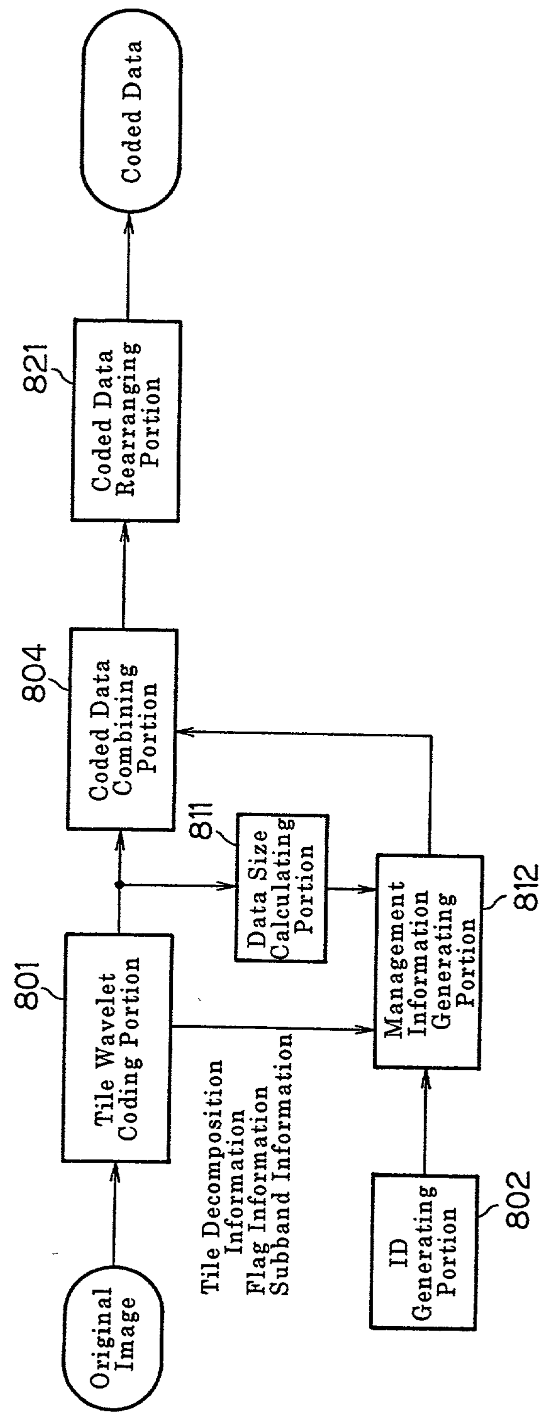

Original Image
801
Tile Wavelet Coding Portion
Tile Decomposition Information
Flag Information
Subband Information
811
Data Size Calculating Portion
804
Coded Data Combining Portion
821
Coded Data Rearranging Portion
Coded Data
812
Management Information Generating Portion
802
ID Generating Portion

FIG.34

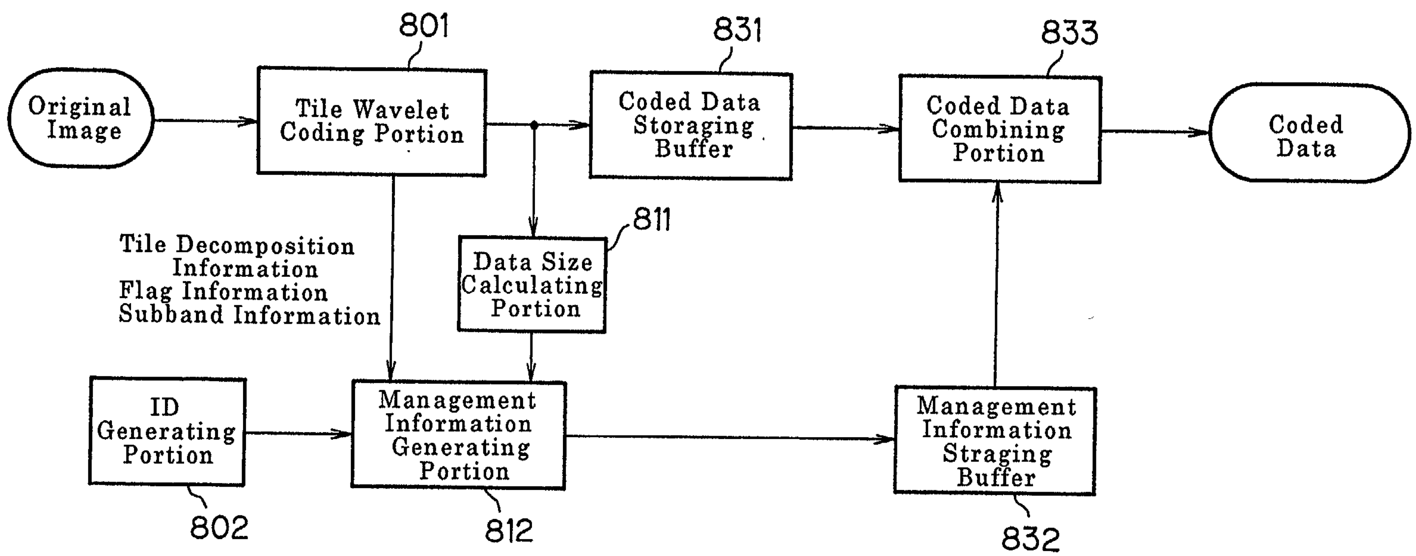

801
831
833
Original Image
Tile Wavelet Coding Portion
Coded Data Storaging Buffer
Coded Data Combining Portion
Coded Data
811
Tile Decomposition Information
Flag Information
Subband Information
Data Size Calculating Portion
ID Generating Portion
Management Information Generating Portion
Management Information Straging Buffer
802
812
832

FIG.35

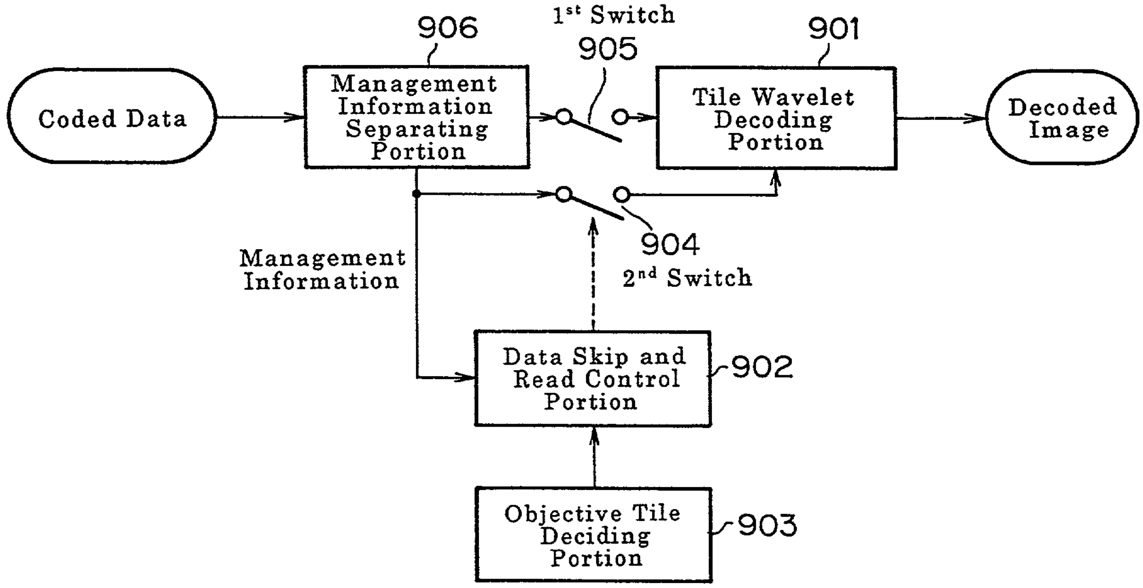
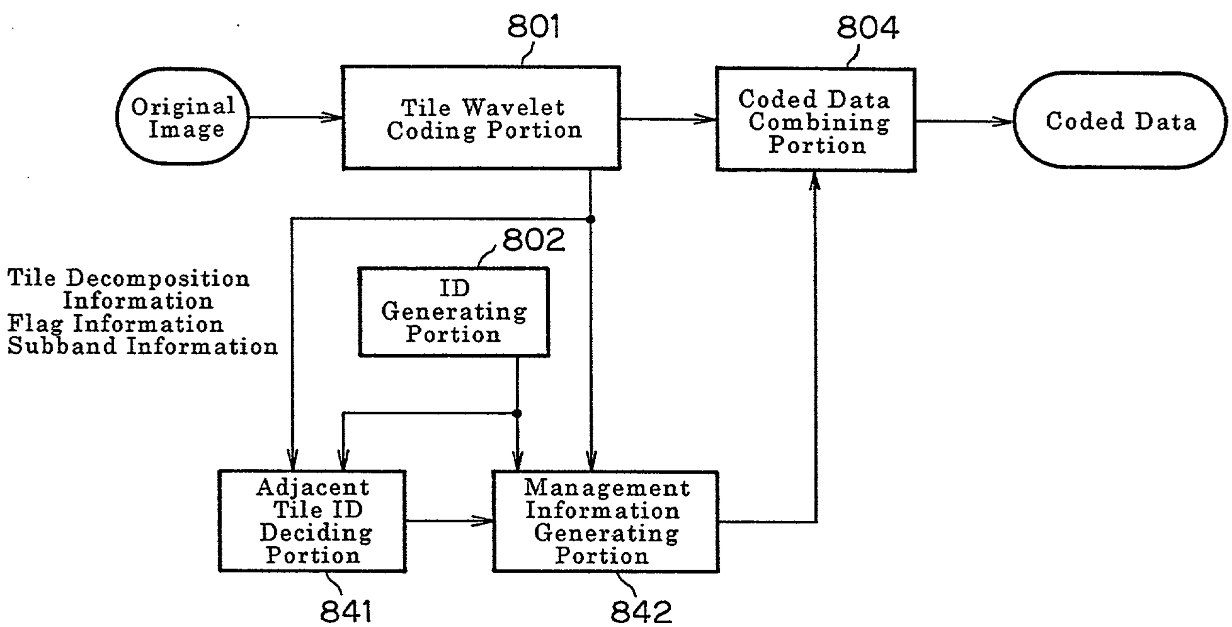

906
1st Switch
905
901
Coded Data
Management Information Separating Portion
Tile Wavelet Decoding Portion
Decoded Image
904
2nd Switch
Management Information
Data Skip and Read Control Portion
902
Objective Tile Deciding Portion
903

FIG.36

(A)


801
804
Original Image
Tile Wavelet Coding Portion
Coded Data Combining Portion
Coded Data
802
Tile Decomposition Information
Flag Information
Subband Information
ID Generating Portion
Adjacent Tile ID Deciding Portion
Management Information Generating Portion
841
842

(B)

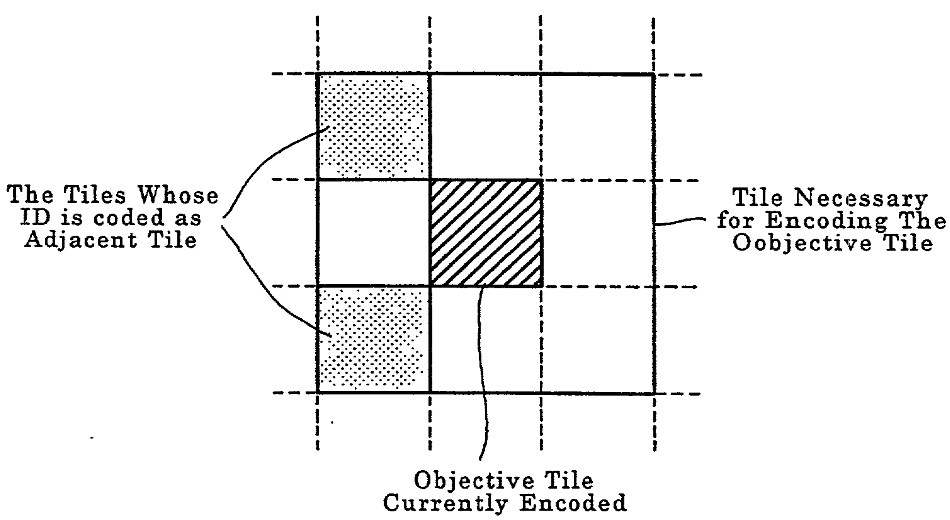

The Tiles Whose ID is coded as Adjacent Tile
Tile Necessary for Encoding The Oobjective Tile
Objective Tile Currently Encoded

FIG.37

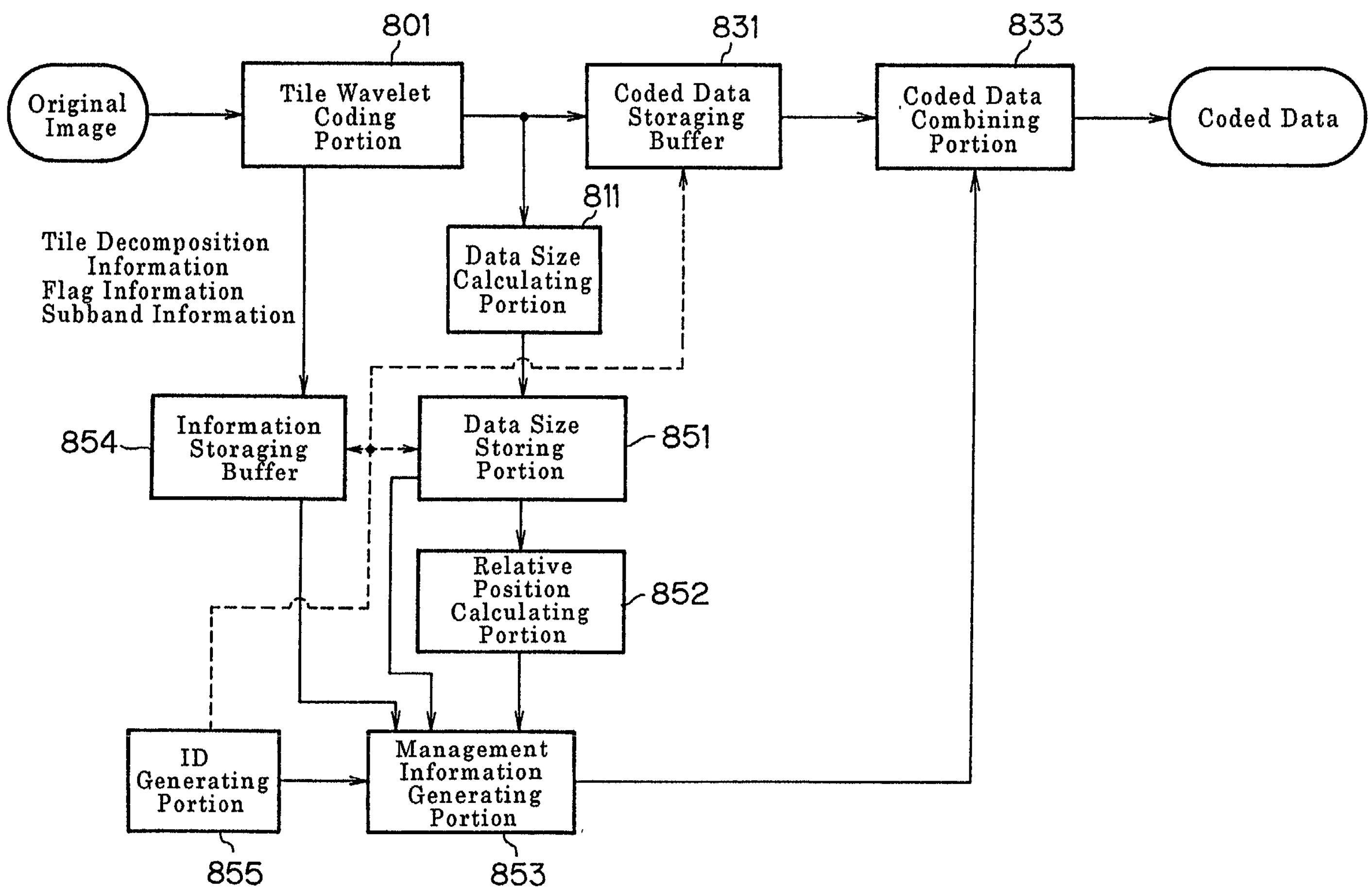
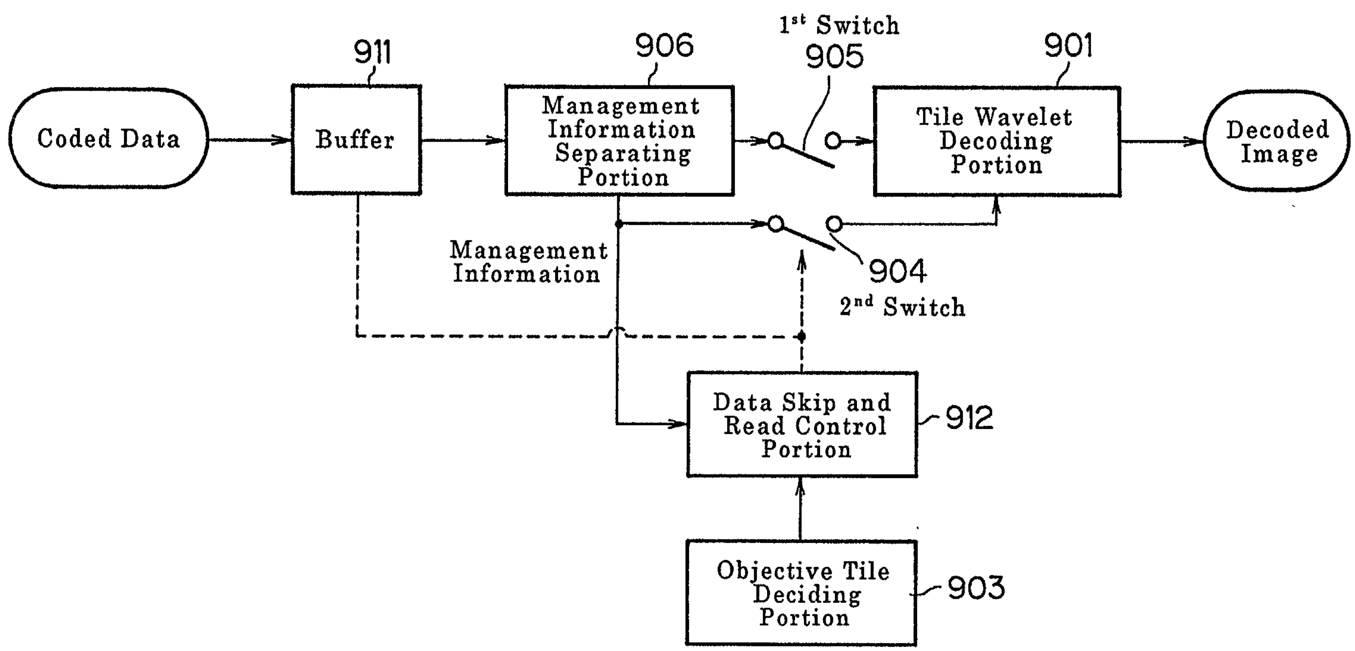

Original Image
801
Tile Wavelet Coding Portion
831
Coded Data Storaging Buffer
833
Coded Data Combining Portion
Coded Data
811
Data Size Calculating Portion
Tile Decomposition Information
Flag Information
Subband Information
854
Information Storaging Buffer
Data Size Storing Portion
851
Relative Position Calculating Portion
852
ID Generating Portion
855
Management Information Generating Portion
853

FIG.38


Coded Data
911
Buffer
906
Management Information Separating Portion
Management Information
1st Switch
905
904
2nd Switch
901
Tile Wavelet Decoding Portion
Decoded Image
Data Skip and Read Control Portion
912
Objective Tile Deciding Portion
903

BIRCH, STEWART, KOLASCH & BIRCH, LLP

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT AND DESIGN APPLICATIONS

ATTORNEY DOCKET NO. 1907-190P

PLEASE NOTE: YOU MUST COMPLETE THE FOLLOWING:

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated next to my name; that I verily believe that I am the original, first and sole inventor (if only one inventor is named below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Insert Title: IMAGE ENCODER AND IMAGE DECODER

Fill in Appropriate Information - For Use Without Specification Attached:

the specification of which is attached hereto. If not attached hereto,
the specification was filed on ______ as United States Application Number ______; and /or
the specification was filed on September 3, 1998 as PCT International Application Number PCT/JP98/03963; and was amended under PCT Article 19 on ______ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (six months for designs) prior to this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Insert Priority Information: (if appropriate)

Prior Foreign Application(s)

(Number)	(Country)	(Month/Day/Year Filed)	Priority Claimed Yes	No
9-254616	JAPAN	September 19, 1997	☒	☐
10-018782	JAPAN	January 30, 1998	☒	☐
10-169456	JAPAN	June 17, 1998	☒	☐
			☐	☐
			☐	☐

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below.

Insert Provisional Application(s): (if any)

(Application Number)	(Filing Date)

All Foreign Applications, if any, for any Patent or Inventor's Certificate Filed More Than 12 Months (6 Months for Designs) Prior To The Filing Date of This Application:

Insert Requested Information: (if appropriate)

Country	Application No.	Date of Filing (Month/Day/Year)

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Insert Prior U.S. Application(s): (if any)

(Application Number)	(Filing Date)	(Status - patented, pending, abandoned)

I hereby appoint the following attorneys to prosecute this application and/or an international application based on this application and to transact all business in the Patent and Trademark Office connected therewith and in connection with the resulting patent based on instructions received from the entity who first sent the application papers to the attorneys identified below, unless the inventor(s) or assignee provides said attorneys with a written notice to the contrary:

16

Terrell C. Birch	(Reg. No. 19,382)	Raymond C. Stewart	(Reg. No. 21,066)
Joseph A. Kolasch	(Reg. No. 22,463)	James M. Slattery	(Reg. No. 28,380)
Bernard L. Sweeney	(Reg. No. 24,448)	Michael K. Mutter	(Reg. No. 29,680)
Charles Gorenstein	(Reg. No. 29,271)	Gerald M. Murphy, Jr.	(Reg. No. 28,977)
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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